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IMPACT OF COHERENCY ON THE PROCESS OF SPECTRAL COMPRESSION OF RANDOMLY MODULATED PULSES

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The study of spectral compression of randomly modulated optical signals is reported. The study of the spectral compression process is carried out for the additive noise model for initial pulses with different coherence time. The studies show that the ratio of spectral compression increases with decreasing of the coherence time of the initial signal.

***Keywords*:** spectral compression, randomly modulated signals, noise filtering, coherence, correlation.

Introduction. Advance in ultrafast optics, photonics, laser physics and, especially, in optical communication transfers the noise suppression and filtering problem from radio-physics to optics, stimulating the studies of self-interaction of randomly modulated optical signals. The nonlinear process of spectral compression (SC), based on self-interaction of optical pulses, initially stretched and chirped in a dispersive medium [1], is of special interest on this view [2]. The spectral compressor consists of prism compressor, as a dispersive delay line (DDL), where the pulse is stretched and negatively chirped, and single-mode fiber (SMF), where nonlinear self-phase modulation leads to the chirp compensation and spectral narrowing [3, 4]: the phase induced by nonlinear self-phase modulation in SMF compensates the negative phase of the pulse obtained in a DDL. The SC process has numerous interesting applications in ultrafast optics and laser technology [5–11]. The spectral temporal imaging of ultrashort pulses through Fourier transformation in the SC systems, and fine frequency tuning along with SC are demonstrated [5]. Applying of SC is proposed in a fiber laser instead of strong spectral filtering to benefit the laser's power efficiency and obtain transform-limited pulses [10]. The urgent applications demand the development of new effective SC systems, and the process efficiency improvements by means of amplitude modulation of signal at the system entry are demonstrated [12].

In this work the SC process for randomly modulated pulses in view of the noise nonlinear suppression and filtering is studied. Particularly, the impact of signal coherency on the SC process based on numerical solution of nonlinear Schrödinger equation for signals with different coherence time is numerically studied.

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Numerical Studies and Results. The pulse propagation in the SMF is described by nonlinear Schrödinger equation for normalized complex amplitude of field [3]:

$$i \cdot \frac{\partial \psi}{\partial \zeta} = -\frac{1}{2} \cdot \frac{\partial^2 \psi}{\partial \eta^2} + R|\psi|^2 \psi, \tag{1}$$

where $\zeta = z / L_D$ is the dimensionless propagation distance, $\eta = (t - z/u)/\tau_0$ is the running time, which are normalized to the dispersive length $L_D = \tau_0^2 / |k_2|$, and initial pulse duration τ_0, correspondingly (k_2 is the coefficient of second-order dispersion). The nonlinearity parameter R is given by the ratio $R = L_D / L_{NL}$, where $L_{NL} = (k_0 n_2 I_0)^{-1}$ is the length of nonlinearity n_2 is the Kerr index of silica, I_0 is the peak intensity. The first and second terms of the right part of Eq. (1) describe the impact of group-velocity dispersion and nonlinearity, correspondingly. The split-step Fourier method during the numerical solution of equation with the fast Fourier transform algorithm on the dispersive step is used. Pulse propagation in DDL is described by Eq. (1) when $R = 0$.

The initial pulses with random amplitude modulation are formed by the model of additive noise [3], and for Eq. (1) the initial conditions are given as follows:

$$\psi(0,\eta) = \psi_0(\eta) + \sigma\xi(\eta) \ . \tag{2}$$

Here ψ_0 is the regular component of normalized amplitude, $\xi(\eta)$ is the stationary noise with a Gaussian correlation function, and σ is its amplitude.

The statistic parameters of radiation are determined by sampling of a large number realizations (N =100), which are solutions of Eq. (1). The studies are carried out for signals with the same value of the noise component amplitude ($\sigma = 0.6$) and different coherence time (τ_c). On Fig. 1 two examples of the randomly modulated initial pulses are shown with correlation times $\tau_c = 0.75$ (a) and $\tau_c = 0.17$ (b). A randomly modulated optical signal with higher coherency (a) has a smoother shape than signal with a lower coherency (b). The period of oscillation is given by the coherence time, and their amplitude is given by the amplitude of noise component.

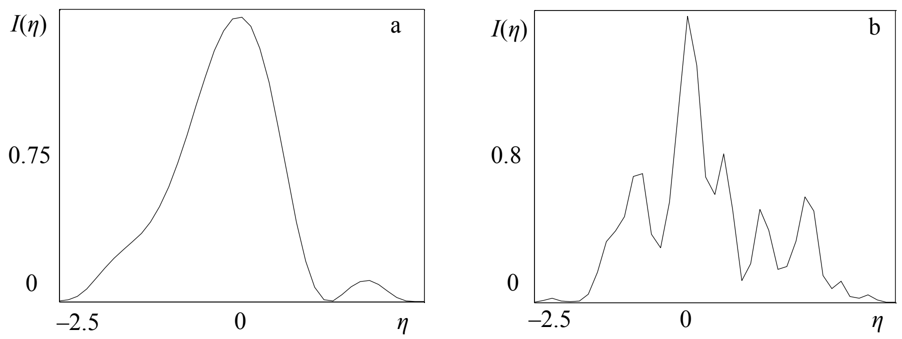

Fig. 1. Two realizations of randomly modulated pulses with the coherence time 0.75 (a) and 0.17 (b).

In Fig. 2 compressed spectra and corresponding pulses for the SMF length f=7 and DDL length d =14 are shown. The lines 1–5 correspond to the $\tau_c =$ 0.75, 0.5, 0.33, 0.25 and 0.17 values of coherence time, respectively.

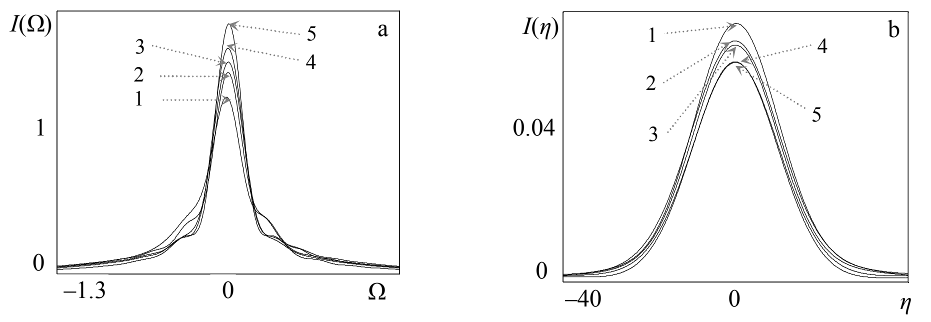

Fig. 2. Average spectra (a) and pulses (b) of spectrally compressed randomly modulated signals with different coherence time $N = 100$, $f = 7$, $d = 14$.

As in Fig. 3 is shown, the SC ratio increases with decreasing of the initial signal coherency. This can be explained in the following way: a signal with the shorter coherence time, i.e. the wider spectrum, is stretching more rapidly in DDL, and the amplitude of random oscillations during the signal is decreasing and such a signal is spectrally compressed more efficiently in the fiber. The maximal value of the SC was 4.27 (Fig. 3). For comparison, SC for the regular Gaussian pulse in the system with the same parameters is implemented ($f = 7$, $d = 14$, Fig. 4). The maximal SC ratio is 5.9 for such a regular Gaussian pulse.

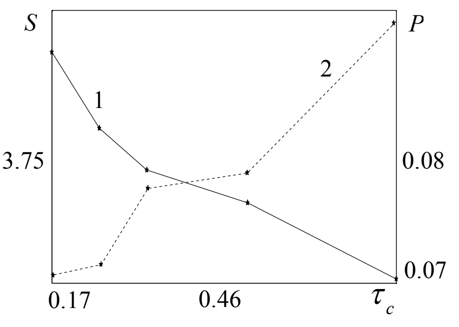

Fig. 3. The SC factor

$$S = I_{in}(\Omega = 0)/I_{out}(\Omega = 0) \quad (1)$$

and pulse stretching factor

$$P = I_{out}(\eta = 0)/I_{in}(\eta = 0) \quad (2)$$

ratios vs coherence time for randomly modulated optical signal. Parameters of SC system and radiation: fiber length $f = 7$, DDL length $d = 14$, $N = 100$, $\sigma = 0.6$.

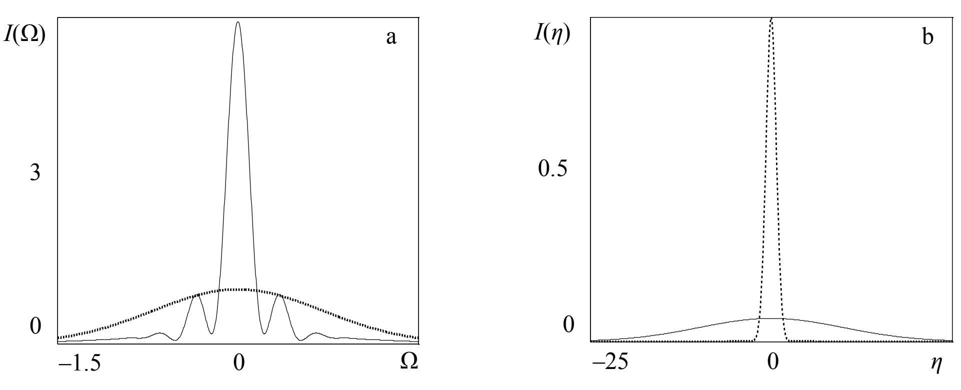

Fig. 4. Initial (dashed line) and compressed (solid line) spectra (a), and corresponding pulses (b) for regular Gaussian signal. The maximum value of SC was = 5.9 ($f = 7$, $d = 14$).

Conclusion. Through detailed numerical study of the nonlinear process of spectral compression for randomly modulated optical signals, the impact of coherency to the process efficiency is investigated. The results of studies show that the spectral compression efficiency increases with decreasing of coherency of the signal to be spectrally compressed.

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