Solitonic Self-Spectral Compression of Noisy Supercontinuum Radiation

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Abstract: We experimentally demonstrate solitonic self-spectral compression for noisy super-continuum radiation in a single-mode fiber. The numerical modeling of the process shows the prospects of the noise nonlinear suppression for partially coherent pulses.
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The effect of solitonic self-spectral compression (self-SC) is recently experimentally demonstrated and analyzed in details [1], as a spectral analogue of soliton-effect compression [2-6]. The self-SC has been observed in a hollow core fiber under combined impact of negative group velocity dispersion (GVD) at 800 nm wavelength and self-phase modulation (SPM). Both the soliton-effect compression and self-SC demand the negative GVD, which can be archived by the use of hollow core photonic crystal fibers, or in common single-mode fibers for radiation with wavelengths higher than 1300 nm. The solitonic self-SC requires strong GVD and weak SPM [1], while for solitonic pulse compression weak GVD and strong SPM are required [2]. Analogically, an effective adiabatic soliton self-SC in a dispersion increasing fiber for pre-chirped pulses, the spectral analogue of adiabatic soliton compression, was also reported [7].

We report the self-SC of noisy supercontinum radiation in a standard single-mode fiber. To reach the wavelength range above 1300 nm, where silica has negative GVD, we generated supercontinuum and cut the spectrum with a longpass filter at 1300 nm. We used Amplitude systems laser with amplifier at 1030 nm with 400-fs pulse duration and 1 kHz repetition rate. We generated the supercontinuum by focusing the radiation with a 3 cm focal length lens on a YAG crystal. After cutting the spectrum, we coupled the radiation into a 600-m long standard single-mode telecom fiber. By controlling the input power with a neutral density filter, we reach the optimal self-SC for the given length of the fiber. Figure 1 shows a 4.1x self-SC of noisy supercontinum radiation.

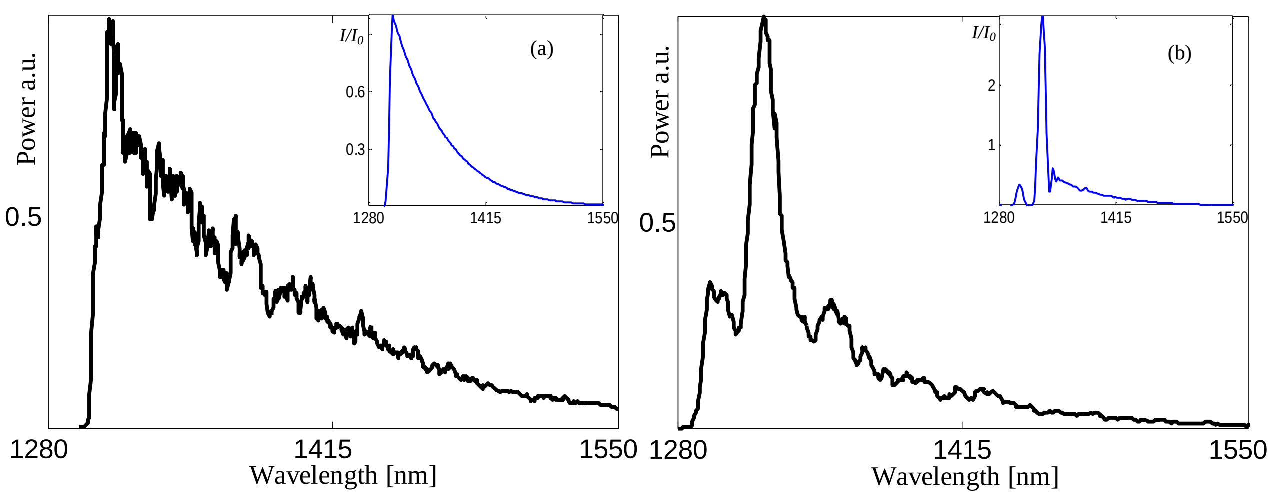

Fig. 1. Solitonic self-SC of noisy supercontinuum radiation.
Supercontinuum spectrum cut at 1300nm (a) and self-compressed spectrum at the output of 600-m long single-mode fiber (b). The inset blue curves show the fitted regular input spectrum (a) and simulated self-SC spectrum (b). Here I is intensity, and I_0 is initial peak intensity.

We also carried out numerical studies of the process, based on the solution of the nonlinear Schrödinger equation. Inset of Fig. 1b is the compressed spectrum, with the shape similar to the experimental result (Fig. 1b). As the supercontinuum has noisy nature, we numerically examined propagation of randomly modulated pulses in a medium with negative GVD and nonlinearity. For the pulses, we used the "signal + noise" model: $A(t)=A_0(t)[1+\sigma\xi(t)]$, where $A(t)=sech(t)$ is the regular component of the pulse amplitude and the $\xi(t)=\xi_{Re}(t)+i\xi_{Im}(t)$ is a stationary complex noise with the σ amplitude, normal (Gaussian) distribution and τ_{corr} correlation time. 3D maps of the pulse and spectrum evolution in the fiber for a randomly modulated pulse show that self-SC is possible even for pulses with noisy nature (Fig. 2). Moreover, the process of self-SC suppresses the noise, resulting in more coherent radiation at the output: a two-peak spectrum is compressed into a single-peak (Fig. 2d), and the noisy pulse is "cleaned" out (Fig. 2c). Fig. 2a,b show the periodic nature of this process, associated with high order solitons.

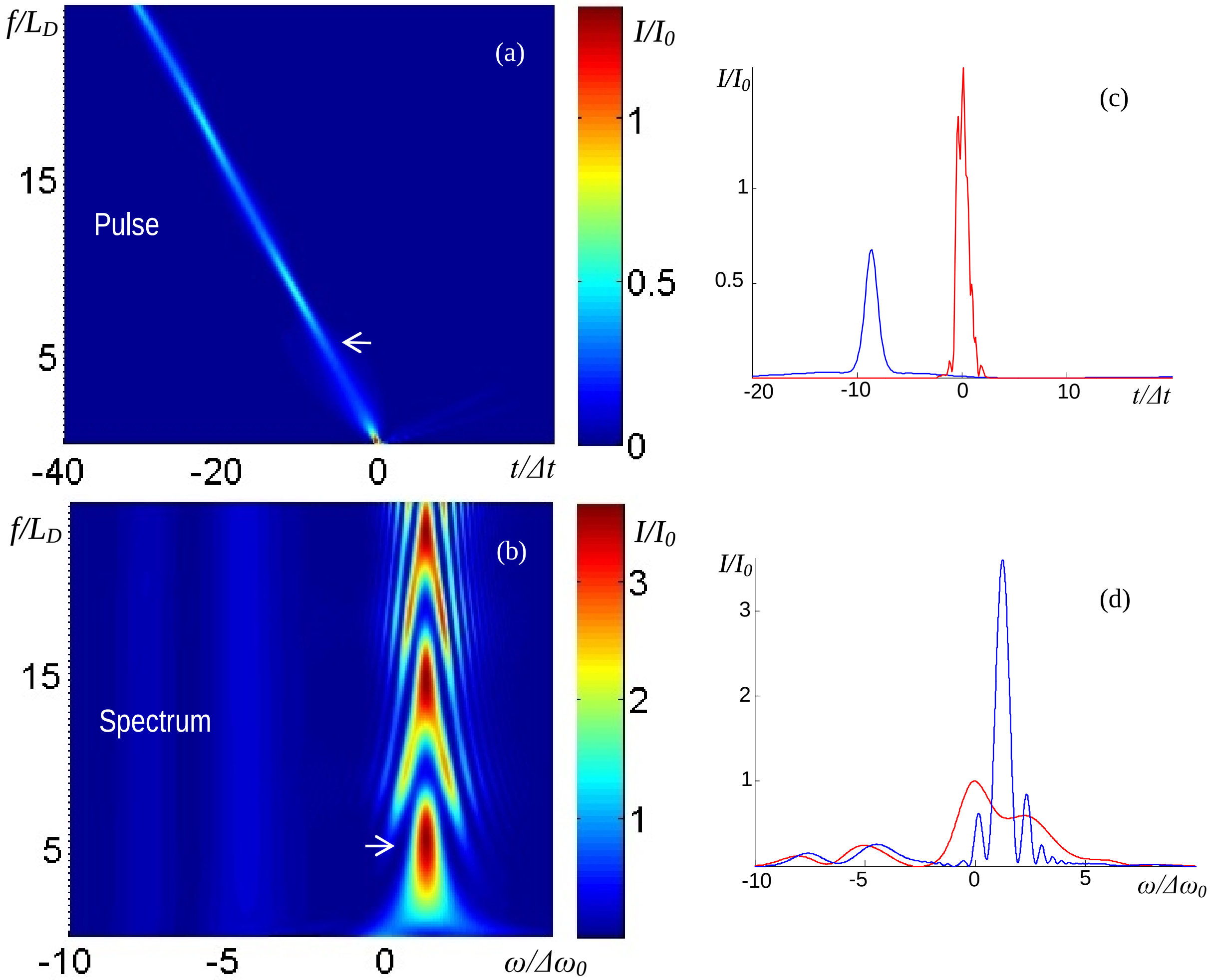

Fig. 2. Solitonic self-SC of a randomly modulated pulse (simulation): 3D map of pulse (a) and spectrum (b) propagation, pulse profile in the input (c; red curve) and on the optimal spectral compression distance (c; blue curve), and spectral profile in the input (d; red curve) and on the optimal spectral compression distance (d; blue curve). Simulation data: σ=2; τ_{corr}=0.2; L_D/L_{NL}=2.2. Here f is the fiber length, L_D and L_{NL} – the dispersive and nonlinear lengths, $\Delta\omega_0$ – initial bandwidth, and ω – centered frequency.

In conclusion, we have experimentally demonstrated 4.1x self-SC of a noisy supercontinuum spectrum in a 600-m single-mode fiber in qualitative accordance with the numerical simulation. Detailed numerical modeling of self-SC for randomly modulated pulses shows that according to its solitonic character the process suppresses the noise, resulting in more coherent radiation.

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