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REGISTRATION	
Title (Ms, Mr, Dr, Prof)	**Mr**
Name	**Minas**
Citizenship	**Armenia**
Institution	**Ultrafast Optics Laboratory, YSU**
E-mail	**minsuqiasyan@gmail.com**

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Author(s) (names and institutions) please underline the presenting author(s)	**Minas Sukiasyan, Aghavni Kutuzyan, Hrach Toneyan, and Levon Mouradian** *Ultrafast Optics Laboratory, Faculty of Physics, Yerevan State University*

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Solitonic Spectral Self-Compression of Randomly Modulated Pulses

Minas Sukiasyan, Aghavni Kutuzyan, Hrach Toneyan, and Levon Mouradian
Ultrafast Optics Laboratory, Faculty of Physics, Yerevan State University
minsuqiasyan@gmail.com

We report the nonlinear process of the spectral self-compression of coherent and randomly modulated pulses in a medium with anomalous dispersion, the spectral analogue of the soliton effect compression, based on the experimental observation and detailed numerical analysis.

The nonlinear process of pulse self-compression, benefitted from the technology of photonic crystal fibers and nanowires, recently demonstrates generation of laser pulses down to a single cycle [1-4]. The process, associated with the shaping of high-order solitons, and also called as soliton-effect compression, occurs under the combined impact of strong self-phase modulation (SPM) and weak negative group velocity dispersion (GVD) [5,6]. In [7], we reported the spectral analogue of this process for transform limited laser pulses, the spectral self-compression, under the conditions when the impact of anomalous GVD exceeds the impact of nonlinear SPM. In this report, we generalize our studies for randomly modulated pulses. The spectro-temporal analogy led to the invention of spectral compression (SC) [8,9], a process with prospective applications in ultrafast optics and laser physics [10-13]. In the SC system, the GVD of the dispersive delay line stretches and negatively chirps the pulse, and the pulse SPM in the nonlinear fiber results in the chirp compensation and spectral narrowing [8,9]. For the self-SC process, the factors of GVD and nonlinear SPM are combined in a single material, e.g., fiber. We observed the self-SC process from 9.62 nm to 7.4 nm in a 2-m hollow-core fiber (HCF; ThorLabs HCF-800) with anomalous dispersion at 800 nm. To study the process nature and peculiarities, we carried out numerical simulations for transform-limited and randomly modulated pulses, based on the solution of the nonlinear Schrödinger equation considering the factors of GVD and Kerr-nonlinearity. We have demonstrated more than 30x self-SC in the result of our numerical studies.

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