Femtosecond pulse self-compression under filamentation of collimated beam

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Few cycle high peak power optical pulses are extensively exploited now in various area of research including attosecond science, high harmonic generation, non-adiabatic laser-matter interaction, etc. Recently it was shown that self-compression down to 8–10 fs without external dispersion compensation could be achieved by loosely focusing of 30–50 fs 30–50 GW 800 nm pulses in noble gases ([1,2,3]). In [4] the new approach was introduced and numerically backed in which self-compression takes place from the initially collimated beam instead of the focused one. Now we exploited this scheme and achieved more than threefold compression of 55 fs 80 GW laser pulses with high energy efficiency and shot-to-shot stability. We traced pulse shape and spectrum changes along the filament in dependence on laser pulse parameters, diameter of the diaphragm inserted into the filament, as well as gas type and pressure and obtained optimal set of characteristics. Numerical simulations well reproduced experimental data and predicted how even higher compression could be achieved.

Single filament was created by 80 GW, 55 fs, 805 nm laser pulse at repetition rate of 10 Hz. To launch filamentation at the proper distance laser beam (M^2=1.8) was telescoped down to the diameter of 1.3 mm. The tube 2–4 m long filled with pure gas of variable pressure (argon, nitrogen, etc.) was placed at 0.5 m away from the telescope exit. We measured energy, temporal and spectral intensity distributions as well as spectral phase (using SPIDER technique) of the radiation passing through the aperture with diameter of 100-1000 μm placed at different positions along the tube.

At the optimal conditions (4.5 mJ input energy, no initial chirp, 0.85 atm Ar pressure, 300 μm diaphragm located 2 m apart from the 0.6 mm thick input silica window of the tube) we obtained 0.3 mJ, 15 fs pulse having good shot-to-shot stability and nearly flat spectral phase (phase deviation not more than 0.2 rad). The compressed pulse has the flat spectral phase with substantial suppression of pre- and post-pulses. Even higher compressed pulse energy of 3-3.5 mJ was obtained when 700 μm aperture was used. Simultaneously the pulse lengthens to 23 fs. At the above mentioned optimum conditions pulse temporal envelope shows remarkable stability. At the pressure ~0.8—0.9 atm we managed to reach both the shortest duration of the self-compressed pulse and the best stability of its duration. The same figure contains numerical data demonstrating that even sub 5 fs pulse can be produced with 100 μm aperture, but it implies much higher beam pointing stability for stable pulse compression.

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1 G. Stibenz, N. Zhavoronkov, G. Steinmeyer, "Self-compression of millijoule pulses to 7.8 fs duration in a white-light filament", *Opt. Lett.,* **31**, 274 (2006).

2 C.P. Hauri., A. Trisorio, M. Merano, G. Rey, R.B. Lopez – Martens, G. Mourou "Generation of high-fidelity, down chirped sub-10fs mJ pulses throught filamentation for driving relativistic laser-matter interactions at 1 kHz"*, Appl. Phys. Lett.*, **89**, 151125 (2006).

3 A. Zaïr1, A. Guandalini, F. Schapper, M. Holler, J. Biegerti, L. Gallmann, U. Keller, A. Couairon, M. Franco, A. Mysyrowicz, "Spatio-temporal characterization of few-cycle pulses obtained by filamentation", *Opt. Exp.,* **15,** 9, 5394 (2007).

4 O.G. Kosareva., N.A. Panov., D.S. Uryupina, M.V. Kurilova, A.V. Mazhorova, A.B. Savel'ev, R.V. Volkov, V.P. Kandidov, S.L. Chin, "Optimization of a femtosecond pulse self-compression region along a filament in air", *Appl. Phys. B.,* **91**, 35 (2008).