Powerful few cycle optical pulse production and new spectral component formation under filamentation in gases

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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. Filaments created during propagation of an ultrashort laser pulses in gases and solids combine high non-linearity with huge intensity and long interaction path. Different non-linear processes were observed such as four-wave mixing, coherent Raman scattering, third harmonic production, etc.

In [1] 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.

The radiation spectrum inside the filament undergone impressive changes along the propagation path. In particular we observed new spectral component on the red side of the initial spectrum. Spectral shift of this component increases along the filament up to 100 nm from the initial wavelength of 800 nm at the distance of 4 m. In the filament core (approximately 300 μm in diameter) this new component amplitude was much higher as compared to the spectral amplitude at the fundamental frequency. Energy of this component was as high as 2 mJ (700 μm aperture) while its duration was estimated as 50–70 fs from the SPIDER measurements. The newly generated spectral components at the red side of the fundamental spectrum take part in the four-wave mixing processes in the filament. As a result new components arise also at the red side of the spectrum.

Hence spectral transformation of collimated radiation undergone filamentation in molecular gases differs drastically from that in noble gases. In particular we did not observed prominent spectral broadening toward blue side in the filament core that is specific for filamentation in noble gases. It is this broadening that provides for efficient self-compression of femtosecond laser pulses down to few optical cycles.

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1 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).