Contribution ID: **50** Type: **not specified**

Multifilamentation. Interaction and reduction of the filaments as nonlinear process.

Tuesday, 29 November 2016 18:40 (20 minutes)

The recent experiments with high power Ti: Sapphire laser pulses demonstrate that it is not possible to produce a homogeneous beam pattern. Hot zones are situated across the beam cross section. Each hot zone self-focuses into a filament, if the intensity and power are high enough. Each of the multiple filaments has a core intensity clamped down to that of a single filament of the order of 0.5-5 TW/cm2. These intensities are two to three orders less than the intensity needed for defocusing by ionization. From other hand, the filaments without ionization of the media were observed in silica, liquids and other materials. The filaments with such intensities attract and exchange energy during their propagation. The final result is that at long distances survived only few of them.
The absence of ionization in these processes forced us to seek other linear and nonlinear mechanisms for description of the above mentioned effects and to answer the following basic questions:
1. What kind is the diffraction of broad-band (attosecond and phase-modulated femtosecond) pulses?
2. What is the physical process that leads to asymmetrical broadband of powerful laser pulse in the early moments of filamentation?
3. What kinds are the mechanisms of merging and energy exchange between the filaments?
Recently in [1] and in some previous works we try to answer of the first question, solving the problem analytically and numerically. The result is that broad-band pulses diffract under new regime with semi-spherical deformation of the intensity profile.
In [2] we try to solve the second question, providing experimental and theoretical investigation of the first picoseconds of formation of white continuum from 100 fs laser pulse in 0.5 cm BK7 glass. We point that the asymmetric spectral broadening of femtosecond laser pulses towards the higher frequencies in isotropic media due to nonlinear effect of cascade generation with THz spectral shift for solids and GHz spectral shift for gases. This shift is equal to three times the carrier-to-envelope frequency. The process works simultaneously with the four-photon parametric wave mixing.
To answer of the third question we investigate in details in [3] and [4] the process of nonlinear attraction between the pulses, due to cross-phase modulation, and energy exchanges due to degenerate four-photon mixing. The results were compared with the experimental results from other authors and demonstrate very good coincidence.
In our Lab there are also first results on nonlinear rotation of the vector of electrical field during process of filament propagation.

[1] A. M. Dakova, L. M. Kovachev, K. L. Kovachev, D. Y. Dakova, "Fraunhofer
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[2] D. Georgieva, L. Kovachev, N. Nedyalkov, "Avalanche parametric conversion in the initial moment of filamentation", Proc. SPIE, 18th International School on Quantum Electronics: Laser Physics and Applications, Sozopol (26-31September 2016), accepted.
[3] L. M. Kovachev, D. A. Georgieva and A. M. Dakova, "Influence of the four-photon
parametric processes and cross-phase modulation on the relative motion of optical filaments', Laser Phys. 25 105402 (7pp), (2015).
[4] Daniela A Georgieva and Lubomir M Kovachev, "Energy transfer between two filaments and degenerate four-photon parametric processes", Laser Physics, 25 035402 (7pp) (2015).

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Session Classification: POSTER SESSION

Track Classification: Poster Session