Atelier
« Modèles et méthodes mathématiques en filamentation laser »
10-14 mars 2014

Workshop
"Mathematical Methods and Models in Laser Filamentation"
March 10–14, 2014

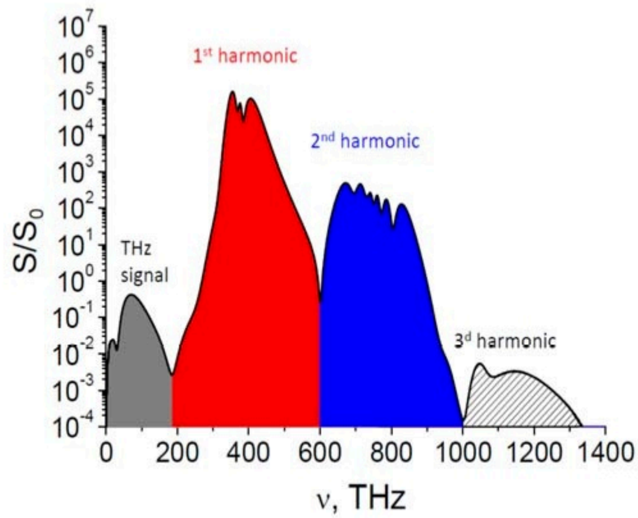
Divergent and confined low-frequency radiation from femtosecond filaments in gases

Olga Kosareva*

kosareva@physics.msu.ru

An extended femtosecond filament is a nonlinear light structure, which can emit a continuum of frequencies as well as quasi-isolated pulses in certain spectral ranges [1-4]. If there is a seed created by means of optical parametric amplifier or other techniques, the conversion efficiency to the desired spectral range can be increased significantly [5]. The specific case is the dual-frequency (800 nm and 400 nm) interaction in the gaseous filament leading to an efficient production of terahertz pulses [6-8]. However, the major part of terahertz radiation from filaments diverges forming a ring in the far-field [9]. The degree of divergence of the newly formed frequencies is crucially important for applications including a distant object inspection. In this paper we use a unidirectional pulse propagation equation model [10] to study numerically the intensity growth, spectral content and spatial divergence of quasi–isolated pulses generated by extended femtosecond filaments in gases. All the newly-created frequencies are generated self-consistently in the course of propagation with the resolution of 0.25 THz. We demonstrate that the major reason for the on-axis propagation of the quasi-isolated pulse centered in the vicinity of 900-1000 nm is the third-order nonlinearity of neutral molecules. The THz pulse at 1-5 THz frequency originates from the free electron photocurrent and propagates in the cone surrounding the filament.

*Department of Physics and International Laser Center, Lomonosov Moscow State University, Leninskie Gory 1, bld 62, Moscow, 119991, RUSSIA.



The Figure shows the spectrum from terahertz to 3d harmonic of the dual-frequency pulse in argon filament. The initial pump pulse has 3.2 mJ energy and 50 fs duration; the initial second harmonic energy is 10 mJ.

We acknowledge support from RFBR (12-02-01368, 12-02-33029), the Council of RF President for Support of Young Scientists (N5996.2012.2), RF President grant for Leading Scientific Schools (NSh-3796.2014.2) Dynasty Foundation, and CEA-France.

References

[1] Aközbek N. *et al.*, Third-harmonic generation and self-channeling in air using high-power femtosecond laser pulses, Phys. Rev. Lett. **89**,143901(2002).

[2] Bergé L. *et al.*, Supercontinuum emission and enhanced self-guiding of infrared femtosecond filaments sustained by third-harmonic generation in air, Phys. Rev. E **71**, 016602 (2005).

[3] Chen Y., Theberge F., Marceau C., Xu H., Akozbek N., Kosareva O., and Chin S.L., Observation of filamentation-induced continuous self-frequency down shift in air, Appl. Phys. B **91**, 219 (2008)

[4] Uryupina D., Panov N., Kurilova M., Mazhorova A., Volkov R., Gorgutsa S., Kosareva O., and Savel'ev A., 3D Raman bullet formed under filamentation of femtosecond laser pulses in air and nitrogen, Appl. Phys. B **110**, 123 (2013).

[5] Theberge F., Akozbek N., Liu W., Becker A., and Chin S.L., Tunable ultrashort laser pulses generated through filamentation in gases, Phys. Rev. Lett. **97**, 023904 (2006)

[6] Cook D.J. and Hochstrasser R.M., Intense terahertz pulses by four-wave rectification in air, Optics Lett. **25**, 1210 (2000).

[7] Xie X., Dai J., and Zhang X.C., Coherent control of THz wave generation in ambient air, Phys. Rev. Lett. **96**, 075005 (2006).

[8] Bergé L. *et al.*, 3D numerical simulations of THz generation by two-color laser filaments, Phys. Rev. Lett. **110**, 073901 (2013).

[9] Klarskov P. *et al.*, Experimental three-dimensional beam profiling and modeling of a terahertz beam generated from a two-color air plasma, New J. of Phys. **15**, 075012 (2013).

[10] Kolesik M. and Moloney J. V., Nonlinear optical pulse propagation simulation: From Maxwell's to unidirectional equations, Phys. Rev. E 7**0**, 036604(2004).

This is joint work with N.A. Panov, V.A. Andreeva, D. Shipilo, A.P. Shkurinov, V.A. Makarov, L. Bergé, and S.L. Chin.