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Light bullets in transparent dielectrics

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Abstract. The state of research of the light bullets (LB) formation in the process of femtosecond laser pulse filamentation is presented. LB is a near single-cycle wave packet that is formed in the result of the light field self-organization in a nonlinear dispersive medium under matched spatiotemporal radiation self-compression in the regime of anomalous group-velocity dispersion (GVD). The formation of each LB is accompanied by the generation of a discrete portion of supercontinuum (SC) in the anti-Stokes region. LB is a short-lived robust object with parameters determined by fundamental properties of the medium and the laser pulse central wavelength.

A LB is an extremely compressed optical wave packet that is formed in the process of femtosecond laser pulse filamentation in transparent dielectrics in the regime of anomalous GVD. In the contrast to the compression of a light beam during self-focusing and to the shortening of an optical pulse duration during phase self-modulation, the formation of a LB with a high energy density occurs as a result of a joint and matched compression of laser radiation both in space and in time with self-action in a nonlinear dispersive medium [1]. Typical LB duration is 1 – 2 optical oscillations, diameter is about few wavelengths, and peak intensity exceeds 10^{14} W/cm^2.

A strong light field in LB leads to the ionization and generation of a low temperature laser plasma, the defocusing in which leads to sharp intensity decreasing on the LB trailing edge. This, in turn, is followed by short wavelength superbroadening of SC spectrum and formation of the narrow isolated anti-Stokes wing (ASW). ASW's bandwidth becomes narrower and its anti-Stokes shift increases with increasing of the initial pulse central wavelength (Fig. 1) [2,3]. The formation of a narrow ASW and a broad minimum in the SC spectrum, which separates ASW from the initial pulse central wavelength, is the result of constructive and, correspondingly, destructive interference of broadband SC radiation generated by a moving LB in a dispersive medium. When a laser pulse peak power is much greater than the critical power for self-focusing a sequence of LBs is formed in the medium. Each LB of the sequence ejects the same portion of energy in the anti-Stokes area of SC [4].

Near single-cycle LB shows a regular 'breathing' in filament that is a cyclic transformation of the light field amplitude and LB's diameter caused by the phase shift between the carrier wave and the wave packet envelope in a dispersive medium. It is shown

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that LB 'breathing', which was revealed by the observation of strictly periodic color centres structures created in isotropic LiF, directly reproduces the influence of extremely compressed wave packet absolute carrier wave phase on nonlinear-optical interactions with medium [5,6]. In the regime of multipulse filamentation induced color centres form a waveguide, during propagation in which the LB's lifetime increases significantly and the frequency-angular spectrum of SC changes qualitatively.

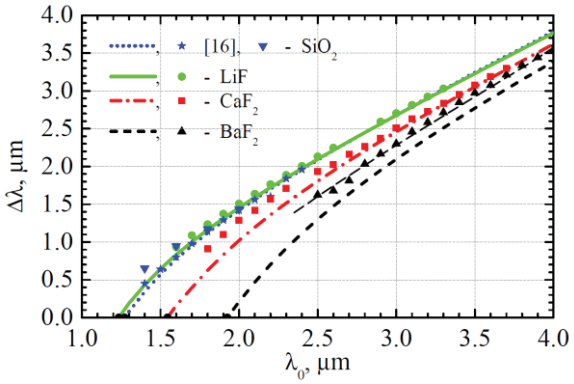

Fig. 1. Shift $\Delta\lambda$ of the wavelength of the SC maximum in the anti-Stokes region from the central wavelength λ_0 of the laser pulse in process of filamentation in regime of anomalous GVD in various materials.

LB is a short-lived robust formation that doesn't depend on spatial and temporal distribution of the light field amplitude and phase in the laser pulse and its parameters are determined by fundamental properties of matter. The LB and LBs sequence filamentation dynamics in transparent media under anomalous GVD have the same general scenario for condensed matter and gas. LB is formed both in a spectrally limited and chirped pulse, both in a collimated beam and in a beam focused by a lens or an axicon [4]. The optimum mode of LB formation is achieved with a matched compression of radiation in both time and space, which is feasible at equal diffraction and dispersion lengths. In this case, a robust LB is formed, the parameters and the spectrum of which don't depend on the energy of initial laser pulse.

References

[1] S.V. Chekalin, V.P. Kandidov, Physics-Uspekhi **56**, 123 (2013)
[2] A.E. Dormidonov, V.O. Kompanets, S.V. Chekalin, V.P. Kandidov, Opt. Express **23**, 29202 (2015)
[3] E.O. Smetanina, V.O. Kompanets, S.V. Chekalin, A.E. Dormidonov, V.P. Kandidov, Opt. Lett. **38**, 16 (2013)
[4] S.V. Chekalin, A.E. Dokukina, A.E. Dormidonov, V.O. Kompanets, E.O. Smetanina, V.P. Kandidov, J. Phys. B **48**, 094008 (2015)
[5] S.V. Chekalin, V.O. Kompanets, A.E. Dormidonov, V.P. Kandidov, Quant. Electron. **47**, 259 (2017)
[6] S.V. Chekalin, V.O. Kompanets, A.V. Kuznetsov, A.E. Dormidonov, V.P. Kandidov, Las. Phys. Lett. **13**, 065401 (2016)