Generation of Stable (3+1)-dimensional High-intensity Ultrashort Pulses

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The spatiotemporal dynamics of high-intensity femtosecond laser pulses are studied based on numerical simulations within an advanced physical model. Beside of the processes involved in the standard cubic nonlinear Schrödinger equation, additional processes describing some crossed space-time effects, quintic nonlinearity, ionization modification of the refractive index, and, for the first time in this model, ionization modification of the group velocity dispersion, are also taken into account. The pulse propagation is described by the nonlinear envelope equation that is capable to propagate ultrashort pulses reaching single-cycle regime. The propagation and the material equations are solved self-consistently. The evolution of the light and the material parameters are studied at realistic experimental conditions. Self-compression of the pulse down to almost single-cycle regime and dramatic increase of the pulse intensity is found. At suitably chosen conditions, the pulse intensity, transversal width and time duration, as well as the spatiotemporal pulse shape become stable with the propagation of the pulse. Such a behavior of the pulse closely resembles a soliton-like formation process. To the best of our knowledge, this is the first observation of stable (3+1)-dimensional propagation of compressed pulses around the single-cycle regime.

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