EGU21-14151, updated on 02 Aug 2021
https://doi.org/10.5194/egusphere-egu21-14151
EGU General Assembly 2021

Femtosecond Laser Pulses Propagation in the inhomogeneous Gas Media

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The present study is devoted to the numerical simulation and analysis of the high-intensity femtosecond LIDAR pulses propagation in the air with a special emphasis on the stimulated Raman scattering (SRS) and the stimulated Raman self-mode (SRSM) processes in optically inhomogeneous gas media.

Numerical models have been developed on the basis of a semi-classical energetic and wave theory, including a set of wave and material equations which allow simulating the gas mixtures, regular or stochastic density inhomogeneity and aerosol particles impact on the femtosecond laser pulse shape and spectrum.

The propagation of laser pulses (λ = 400, 800 nm; τ = 1 ÷ 30 fs) with positive or negative chirp was numerically investigated in pure gases: H_2, N_2, O_2 and their typical atmospherically mixtures.

The media density or composition (aerosol) inhomogeneity was simulated depending on the ratio between the path length (D), the size of the inhomogeneity (l) and the mean wavelength of pulse spectrum (λ). For D >> l the inhomogeneity impact was considered as a stochastic, while in the case of D < l the inhomogeneity was simulated having a constant gradient along the pulse track.

For vertical sounding tracks the real atmospheric air density profiles were used.

Aerosol density and size fluctuations were estimated as 5÷30% to the mean value.

In model testing regime the SRS and SRMS modes of the femtosecond laser pulse propagation for tracks of up to 100 m have been calculated for investigating the dynamics of the pulse shape, spectrum and energy change under different initial conditions.

The SRMS mode for 10, 14 and 20 fs laser pulses with energy areas of 3π, 2π, π, π/100 was numerically investigated in different gas and aerosol compositions for tracks of βz = 0.5 ÷ 20, where z is the space coordinate and β – the inverse value of Raman self-scattering defined by the media.

The results obtained show that the dynamics of pulse propagation in SRMS mode is nonlinear in the pulse shape and spectrum. Moreover, the SRMS mode having a resonance character for 2π-pulses may be misaligned as well as modulated by the inhomogeneity of the medium.