Anti-Stokes Wing Shift on External Focusing Change Under Mid-IR Filamentation in Dielectrics

K V Lvov[1], S Yu Stremoukhov[1,2], and F V Potemkin[1]

[1]*Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia*
[2]*National Research Center "Kurchatov Institute", Moscow, Russia*
Contact Email: lvov.kv14@physics.msu.ru

External focusing variation is a simple way to control nonlinear processes and to improve the efficiency of coherent radiation generation [1-3]. The supercontinuum spectral extension can be efficiently controlled by varying the phase mismatch parameter by changing the focusing condition in the normal group velocity dispersion (GVD) regime [4].

In this paper, we numerically investigate the role of external focusing in anti-Stokes wing (ASW) shift under filamentation of 200 fs mid-IR laser pulses (4.4 μm) in CaF_2, which has anomalous GVD in this spectral range. We perform calculations of 1–300 μJ laser pulse propagation within CaF_2 for focal length in the range from 6 to 20 cm. The numerical model utilizes the unidirectional pulse propagation equation (UPPE) [5], Keldysh formula for photoionization rate and single-rate ionization model for impact ionization.

Since CaF_2 has a negative GVD at 4.4 μm, at the particular point, pulse splitting occurs that leads to the anti-Stokes wing (ASW) formation. The position of ASW maximum can be extracted from the resonant relation [6]. Based on the simulation, we conclude that the tighter the focusing, the larger the ASW red-shifting. This tendency can be explained by modified resonant relation, which includes refractive index changing by the self-focusing and free-electron defocusing. Generated free-electron plasma modifies the resonant relation. Therefore, when external focusing is applied, the ASW experiences a red-shift due to the increased free-electron density.

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