Ilbaganges šviesos gijos atmosferos skaidrumo lange

Long-wavelength filaments in the atmospheric transparency window

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Following a steady progress in the development of mid-IR optical parametric chirped pulse amplification (OPCPA) technology [1] first successful demonstration of mid-IR filaments in ambient air was recently achieved [2] initiating a vigorous debate in the community on the filamentation mechanisms in the mid-IR. Substantially lower ionization rates cause significantly smaller electron plasma densities in mid-IR filaments as compared to the case of filaments generated by more common 800-nm and 1030-nm near-IR drives. Because of the low plasma density alternative mechanisms responsible for the intensity clamping and the arrest of the self-focusing collapse, namely, a saturation of higher order Kerr nonlinearity terms or shock driven walk-off of generated harmonics, have to be considered. Additionally, since mid-IR spectral range contains numerous vibrational resonances, an additional mechanism of losses, i.e., absorption of spectral components generated in a filament due to the spectral broadening needs to be considered next to ionization [3], rotational Raman excitation [4], and plasma absorption [3, 4]. Furthermore, GVD of air it the vicinity of 3.6 μm changes from positive to negative [5] which makes filamentation dynamics even more complicated and sensitive to the experimental conditions.

In this contribution we examine experimentaly properties of filaments ignited by multi-millijoule, 90 fs mid-IR pulses centered at 3.9 μm. The filaments are characterised by monitoring plasma density distribution and losses as well as temporal and spectral dynamics and beam profile evolution at different focusing strength. By strengthening focusing we observe a shift from plasma assisted filamentation to filaments with negligible plasma content. In the case of very low if any plasma density filamentation manifests itself by beam self-symmetrization and spatial self-channeling. Spectral dynamics in the case of loose focusing are dominated by the Raman red shift, which leads to the overlap with CO_2 resonance in the vicinity of 4.2 μm. Dynamic CO_2 absorption plays an important role in filamentation of 3.9 μm pulses and either alone or together with other nonlinear processes is responsible for the arrest of intensity. Finaly we show that filamentation of 3.9-μm pulses is very sensitive to temporal/spectral phase of mid-IR pulses. By controlling the chirp one can achieve 3D self-compression which leads to a formation of mid-IR light bulets.

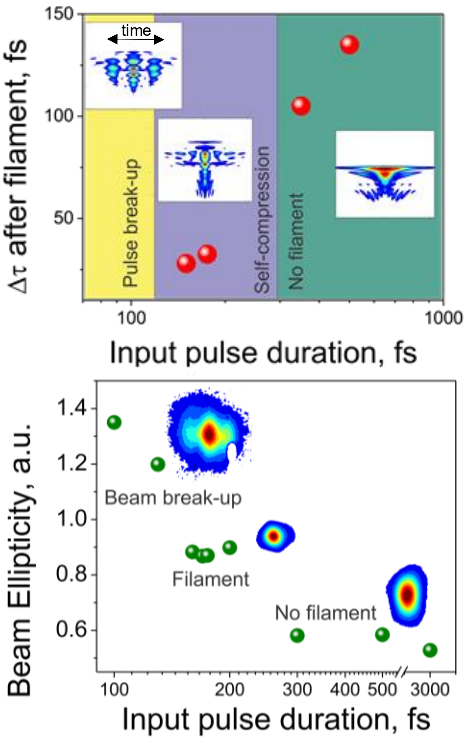

Fig.1 Input pulse duration dependent temporal (top panel) and spatial (bottom panel) profiles of mid-IR pulses after filamentation in ambient air.

Keywords: ultrafast non-linear optics, mid-infrared, filamentation.

Literature

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