

Self-compression and four-wave mixing of femtosecond laser radiation under filamentation of collimated beam in gases

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Filaments generated during femtosecond laser propagation in gas media is substantial support for different non-linear processes realization, for example, ultra-short pulse generation, four-wave mixing, coherent Raman scattering, third harmonic production and others. In the paper we report on investigation of new spectral components formation and self-compression of radiation under filamentation of pre-collimated laser beam in molecular and noble gases. At collimated regime filament length is much more than at the focused geometry. This circumstance allows one to become clear effects of wave mixing and to trace spatial changes of pulse spectra and envelope.

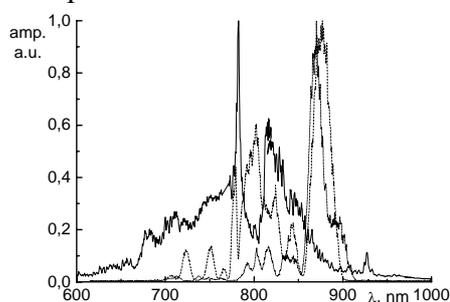


Fig.1 Spectra of radiation in filament created in Ar (solid line), N₂ (dashed line) and air (dotted line) measured with 200 μm aperture

The spectral transformation of collimated radiation which underwent filamentation in molecular gases differs drastically from that in noble gases (see Fig.1). In particular we did not observe prominent spectral broadening towards blue side that is specific for filamentation in noble gases and essential for efficient self-compression of femtosecond laser pulses down to few optical cycles. At the same time in molecular gases the new bright spectral component appears due to Raman scattering. Spectral amplitude of this component measured in aperture with diameter of 200 μm in air more than seven times exceeds the amplitude of radiation at fundamental wavelength (see Fig.1). The central wavelength of this spectral component moves towards infra-red area with increase of the radiation propagation length and can be easily controlled by adjusting the chirp of the initial laser pulse. The gas pressure also drastically affects the observed picture: at nitrogen pressures below 0.6 atm this component has negligible spectral amplitude. All of this permit us to suppose semi-solitonic regime of radiation propagation. Measurements by SPIDER (see Fig.2) show that in molecular gas in the filament core we obtained single pulse with central wavelength shifted towards IR and duration of about 60 fs. One can also notice that in argon we obtained single very short pulse with duration down to 13 fs.

In the experiment single filament was created by 80 GW, 55 fs, 805 nm laser pulse at repetition rate of 10 Hz. To launch filamentation at the proper distance laser beam ($M^2=1.8$) was telescoped down to the diameter of 1.3 mm. The tube 2–4 m in length filled with pure gas of variable pressure (argon, nitrogen, etc.) was placed 0.5 m far from the telescope exit. We measured energy, spectrum envelope and phase (using SPIDER technique) of the radiation passing through the aperture with diameter of 100-1000 μm placed at different positions along the tube.

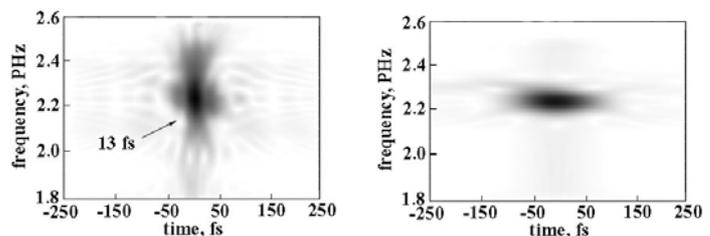


Fig.2 The reconstructed polarization gate FROG images for pulses registered with argon and air in 500 μm aperture.

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