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

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Concerned effects

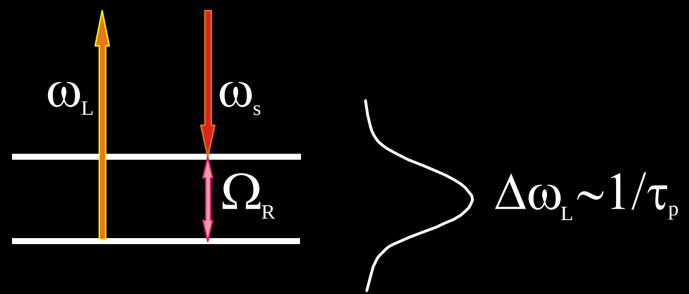
- laser pulse self-compression in noble gases

Spectra broadening →
- Self-phase modulation
- Self-steepening
- Plasma blue wing

Pulse compression → Negative dispersion in plasma $(\Delta n = -\frac{1}{\omega^2})$

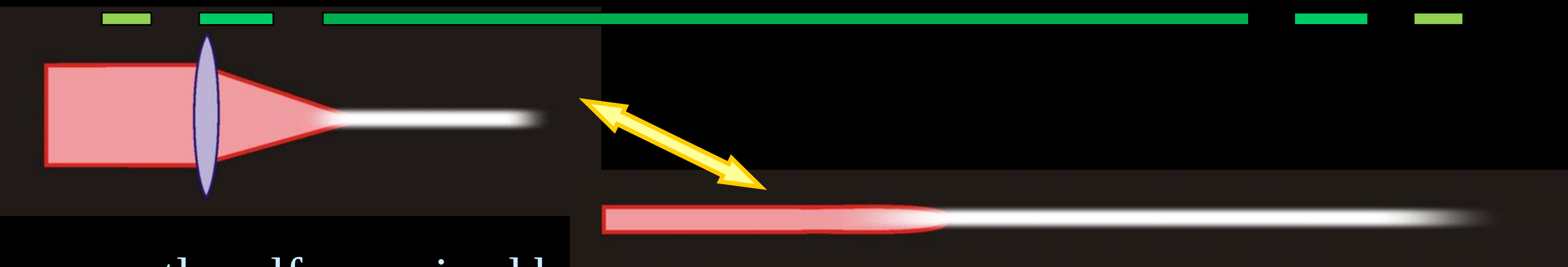
- influence of Raman scattering and four-wave mixing on laser pulse spectra and envelope in atomic gases

for femtosecond pulses:



- appearance of new components in spectra of radiation
- Raman soliton generation (plasma in filament core can serve as a media with negative dispersion)

Collimated beam vs focused one



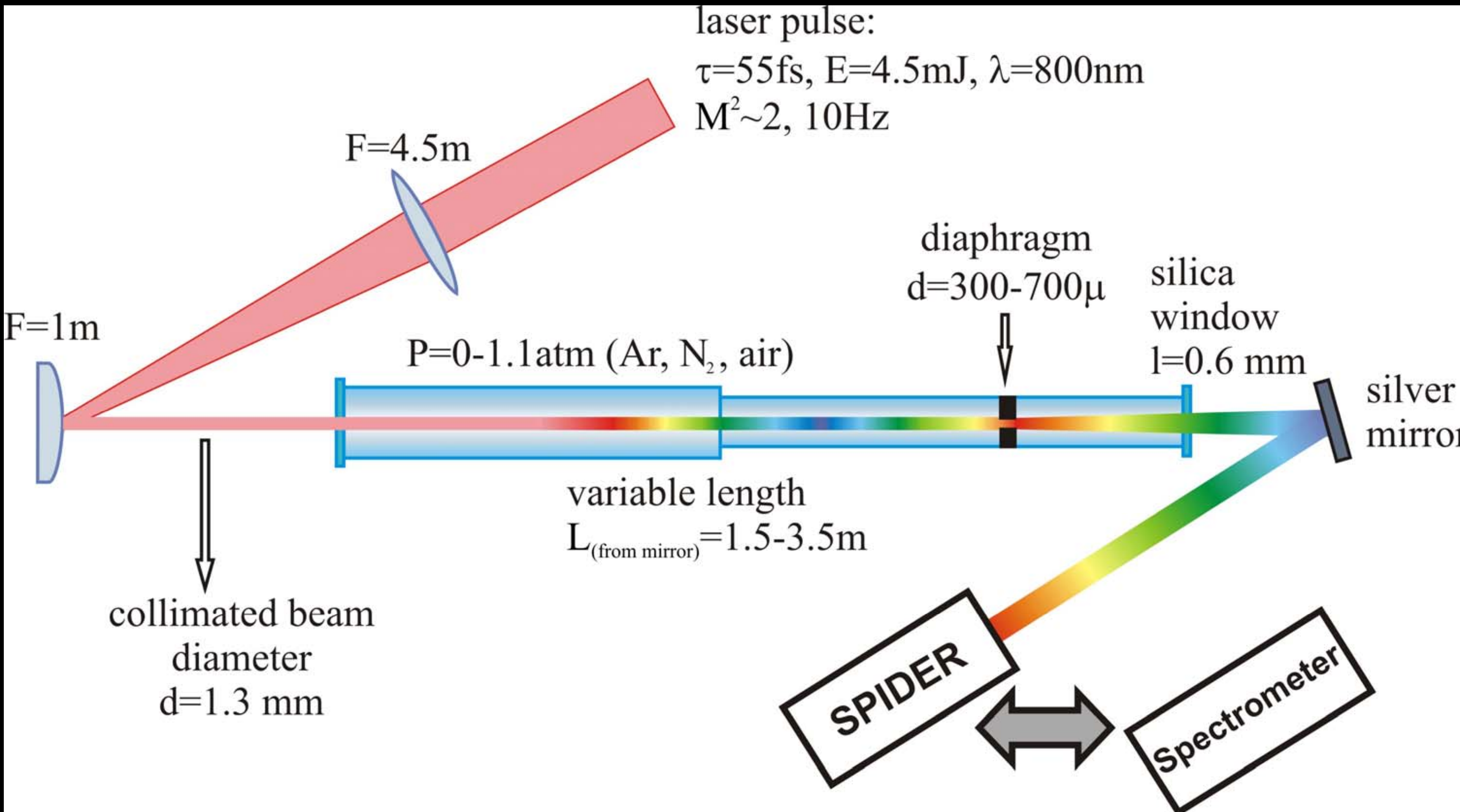
• gentle self organized beam collapse helps to avoid inevitable instability caused by gas breakdown by the focused beam. This provides higher stability of the output parameters of the compressed pulse.

• parameters of the compressed pulse in the collimated beam geometry slightly depend on fluctuations of the parameters of the initial pulse (energy, duration).

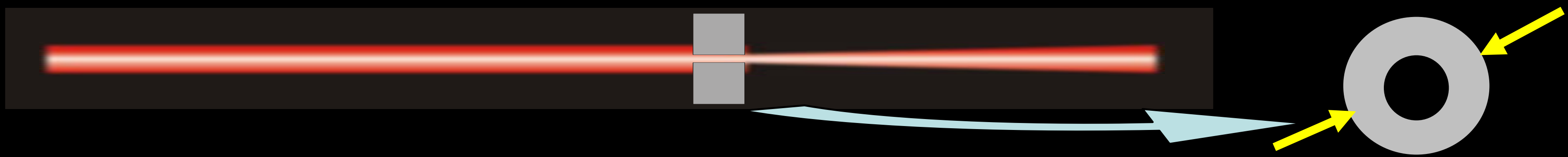
• one can extract compressed pulse with optimal parameters placing an aperture at appropriate position.

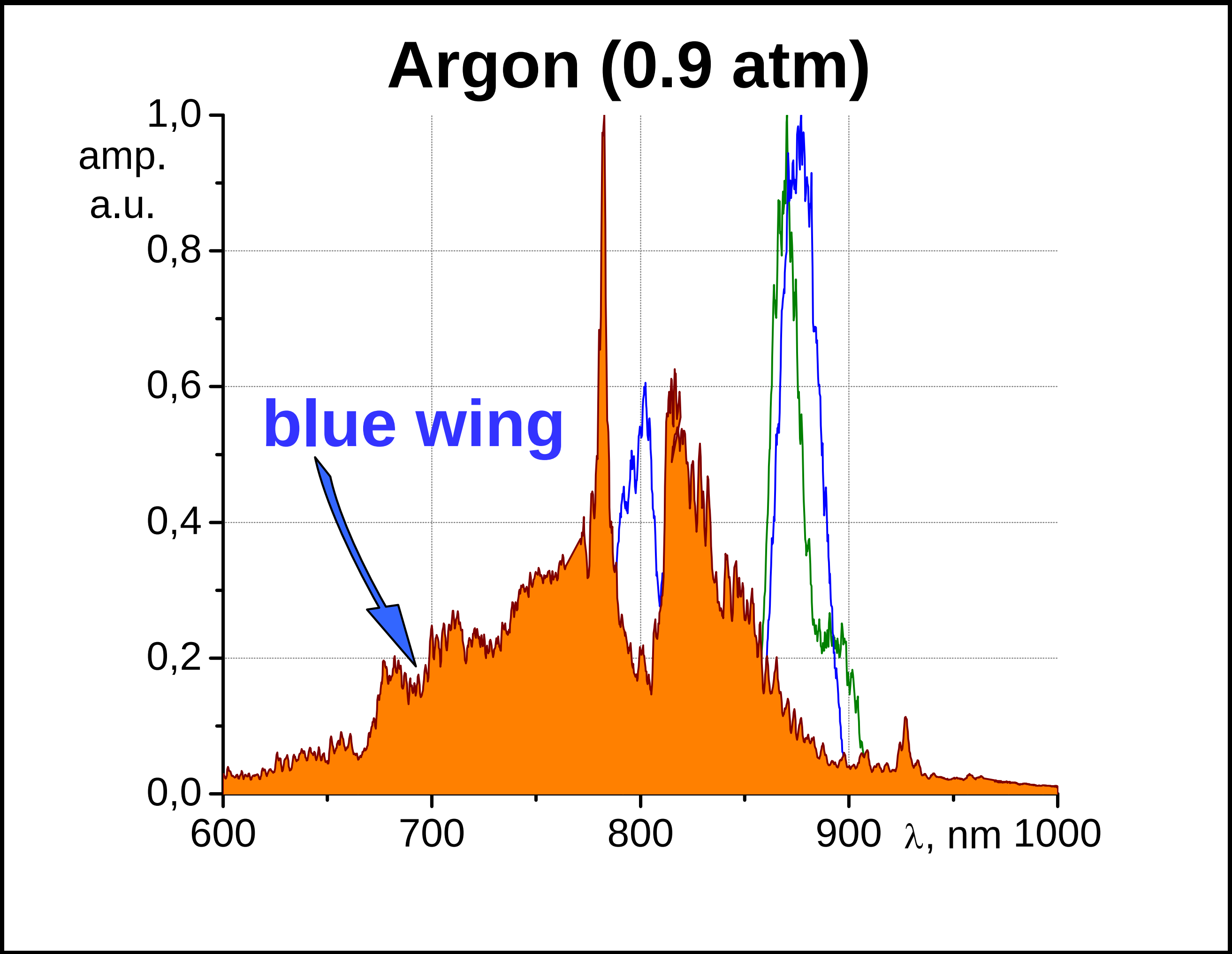
• longer interaction length permits to became apparent wave mixing processes

Experimental setup



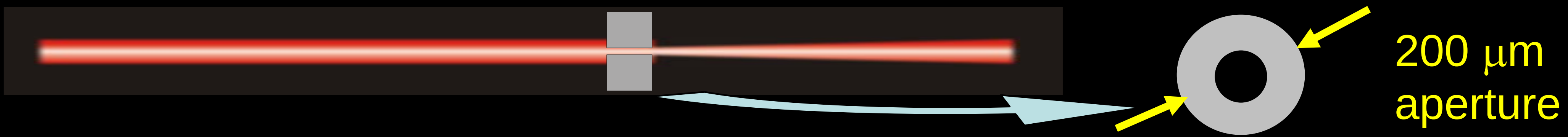
Spectra peculiarities in noble and molecular gases

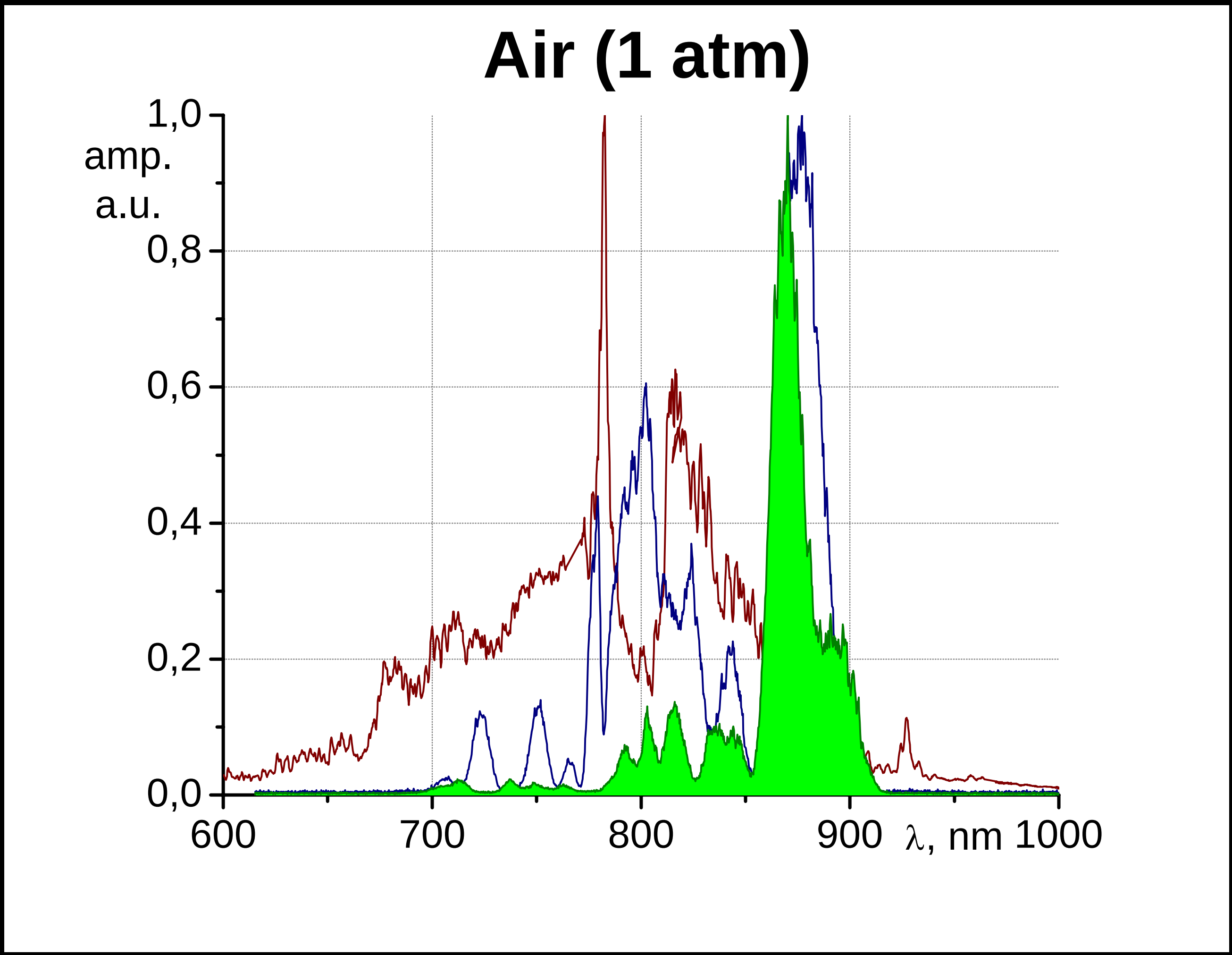




Spectra is widened up to 300 nm from 30 nm in initial laser pulse

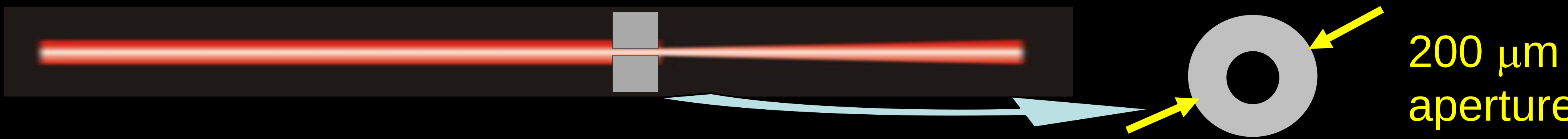
Spectra peculiarities in noble and molecular gases

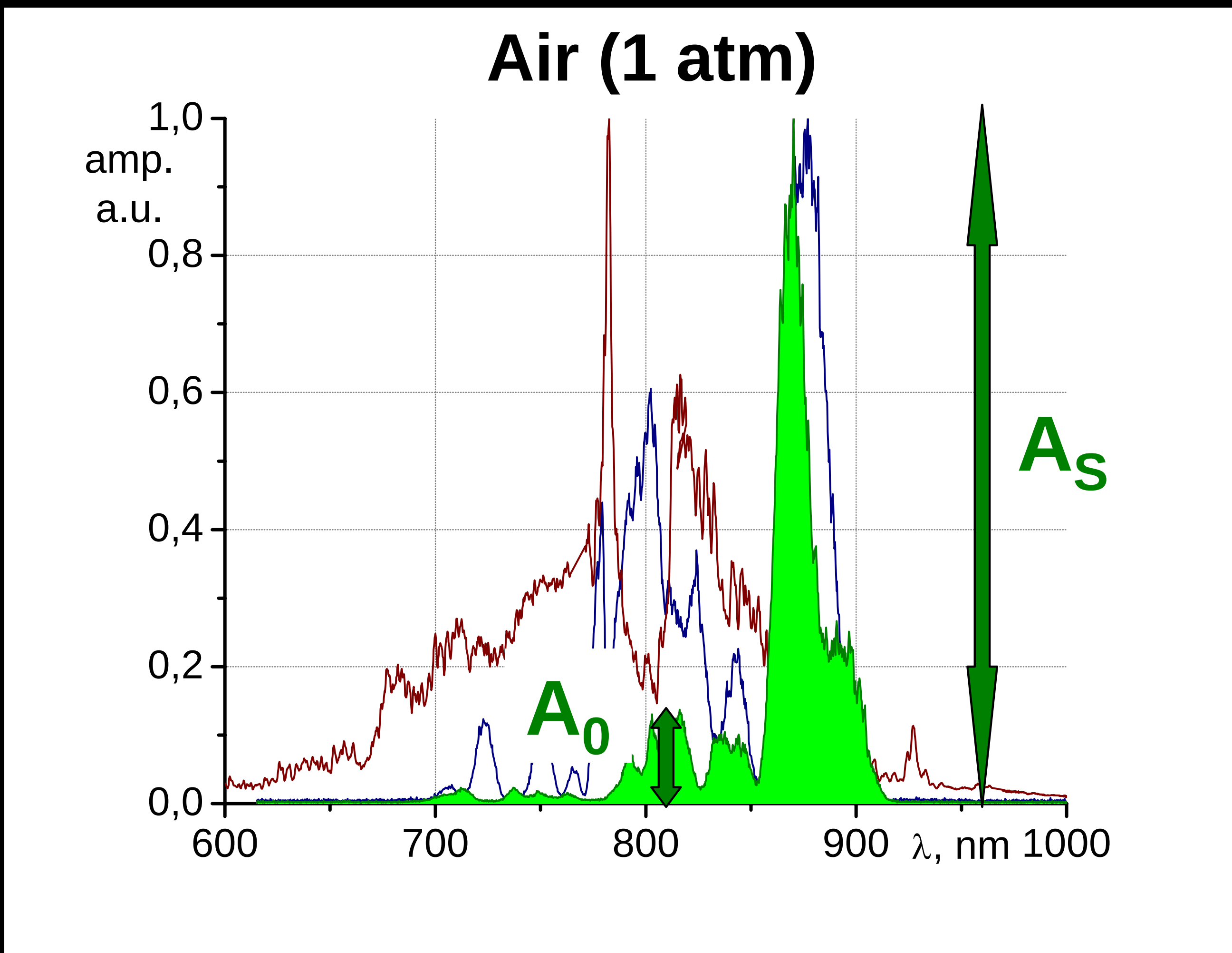




Raman spectral component is generated.

Spectra peculiarities in noble and molecular gases



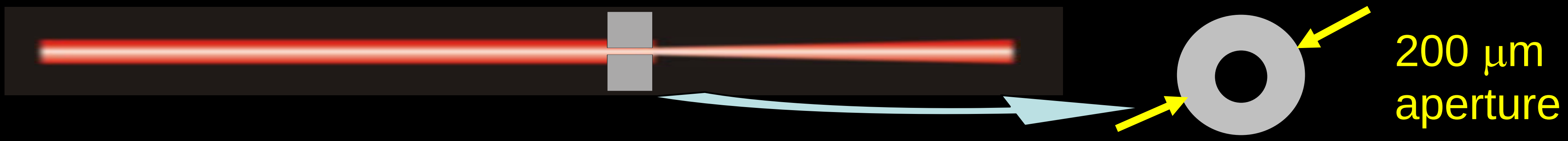


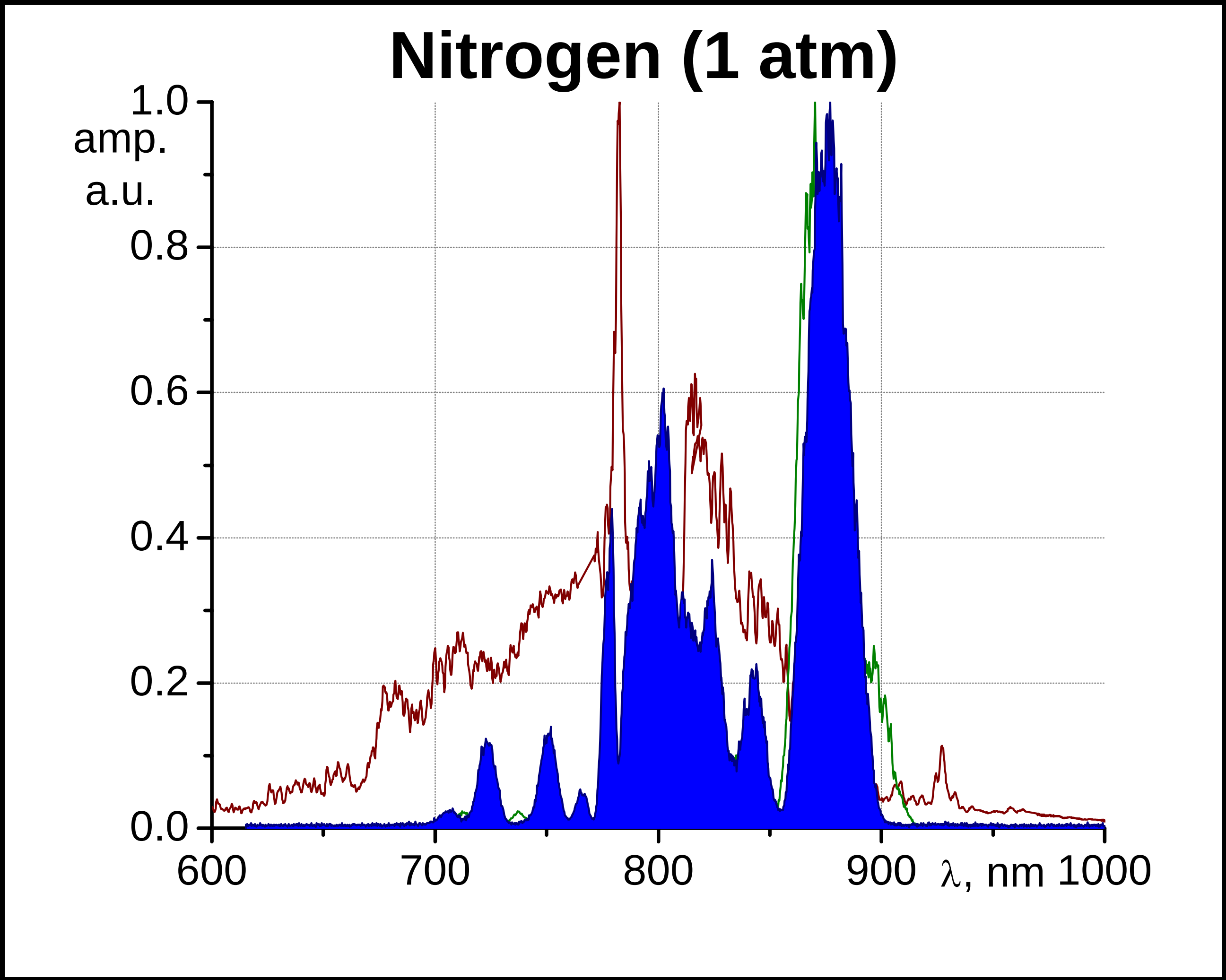
Raman spectral component is generated.

in filament core

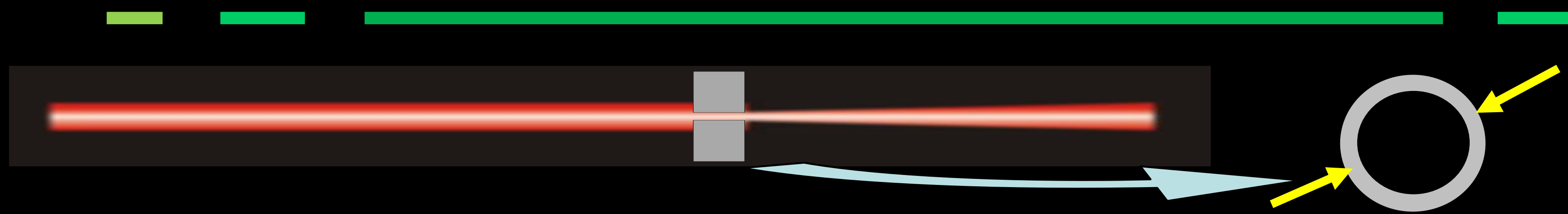
$A_S/A_0 \sim 7$

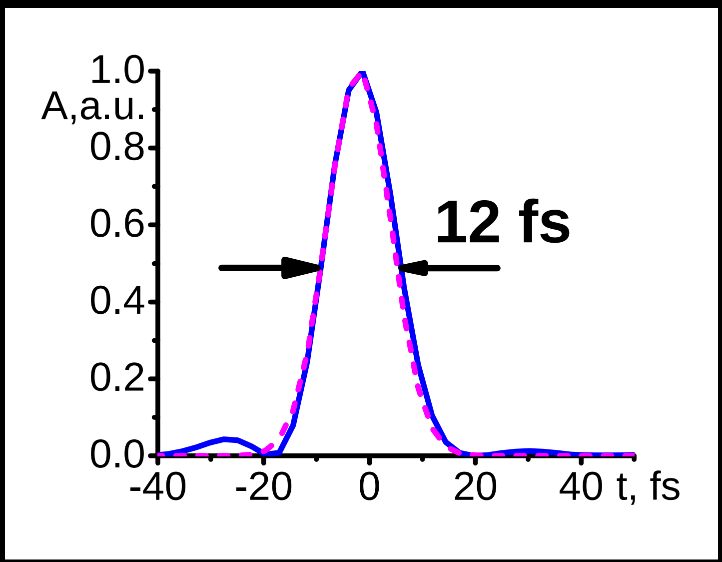
Spectra peculiarities in noble and molecular gases

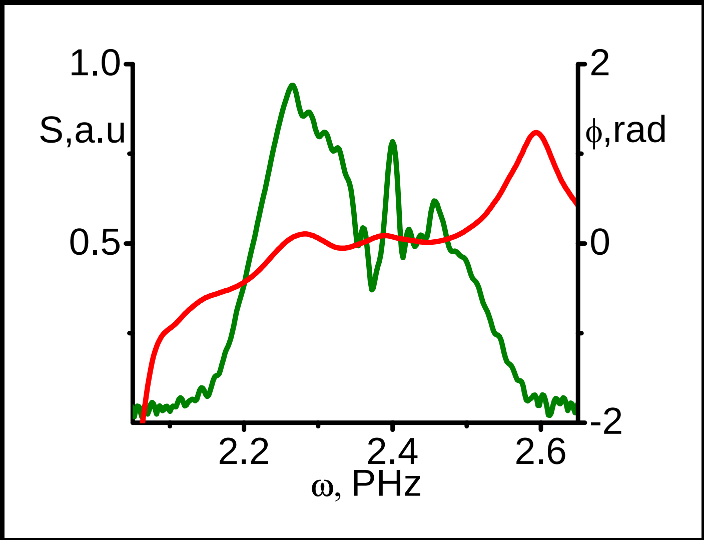




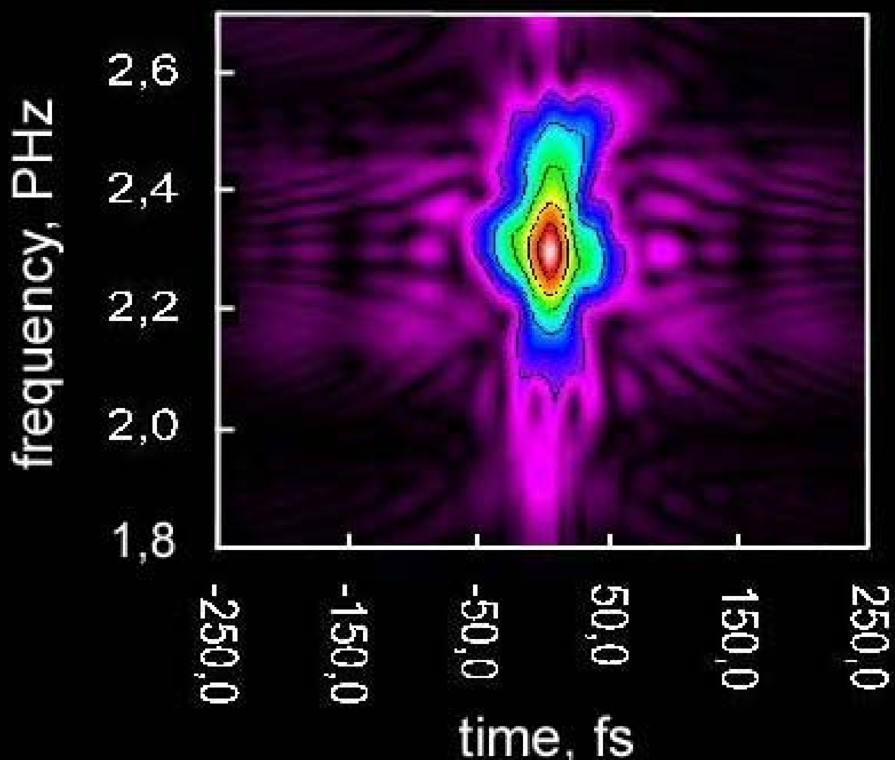
Laser pulse self-compression in argon







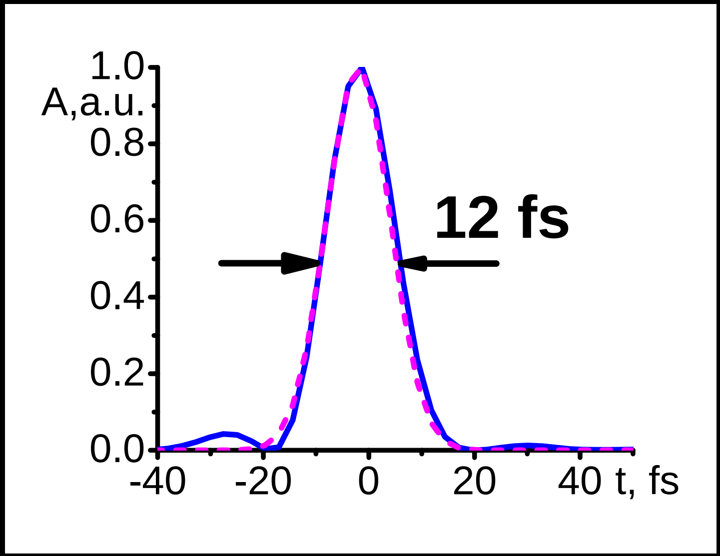
Argon, P=0.9 atm, L = 285 cm

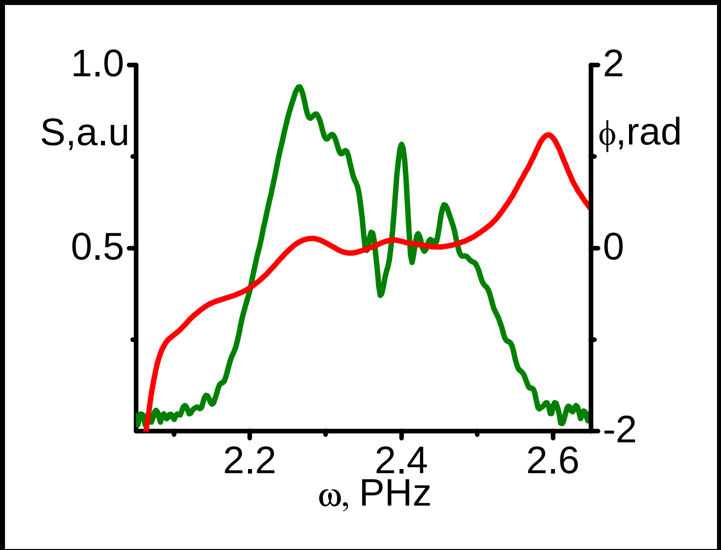


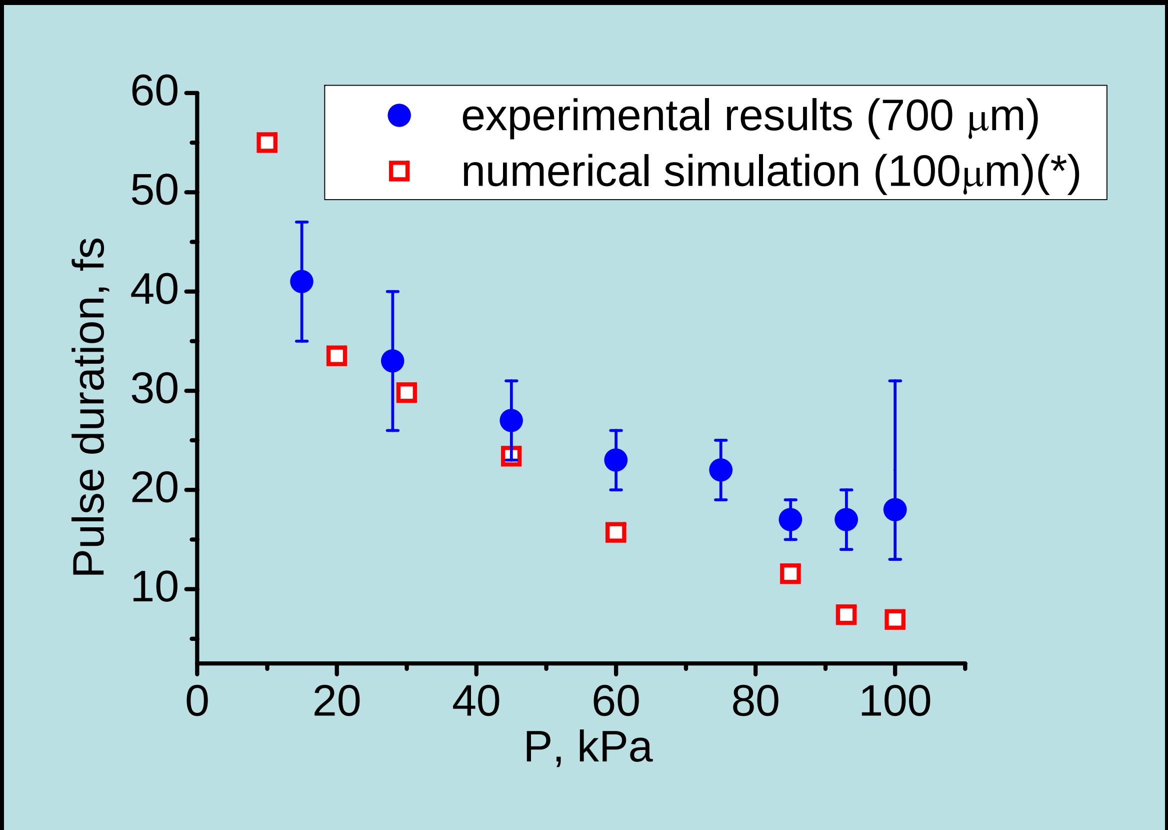
Pulse energy ~ 1.5 mJ

Essential suppression pre- and post- pulses

Laser pulse self-compression in argon



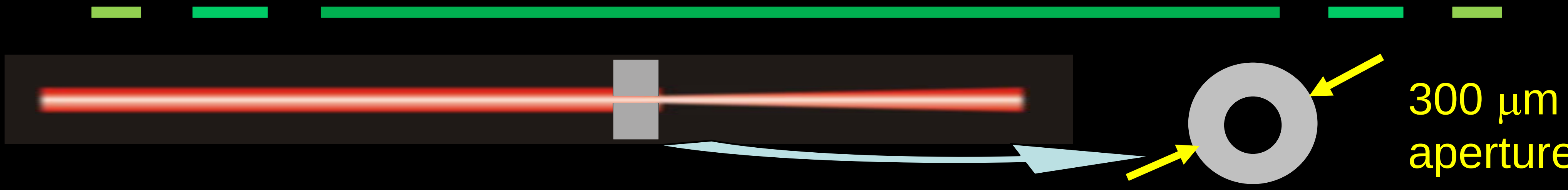


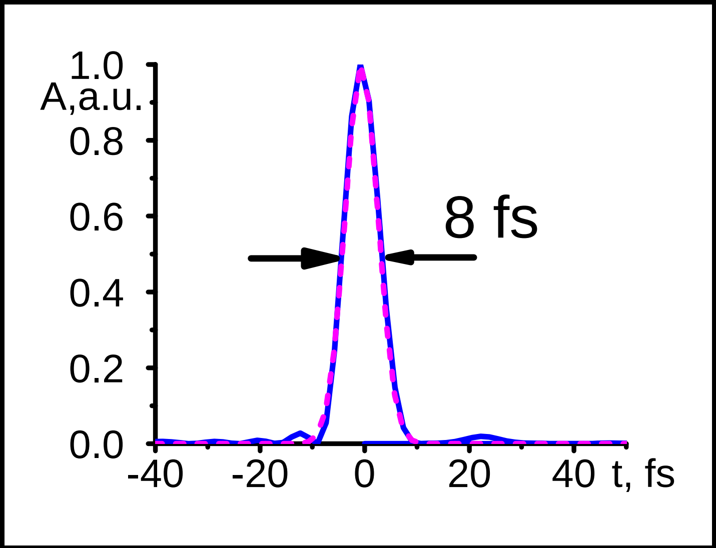


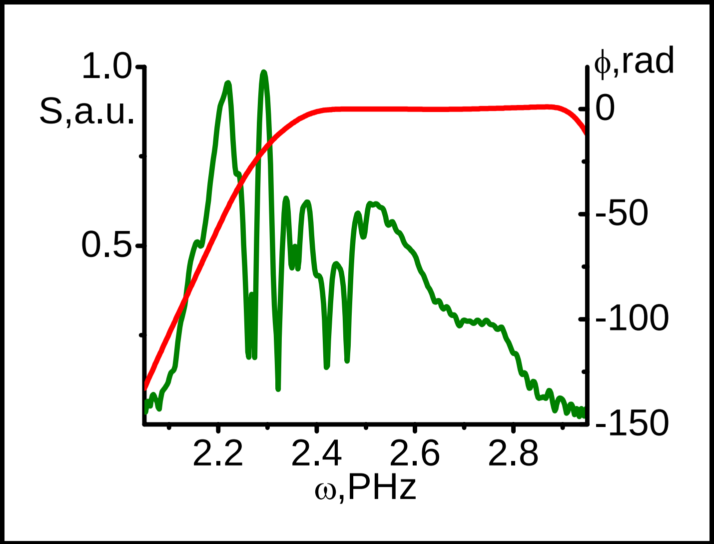
(*) O.Kosareva, N.Panov

Short pulse (t_p~15+/-3 fs) is generated in about 90% of laser shorts.

Laser pulse self-compression in argon







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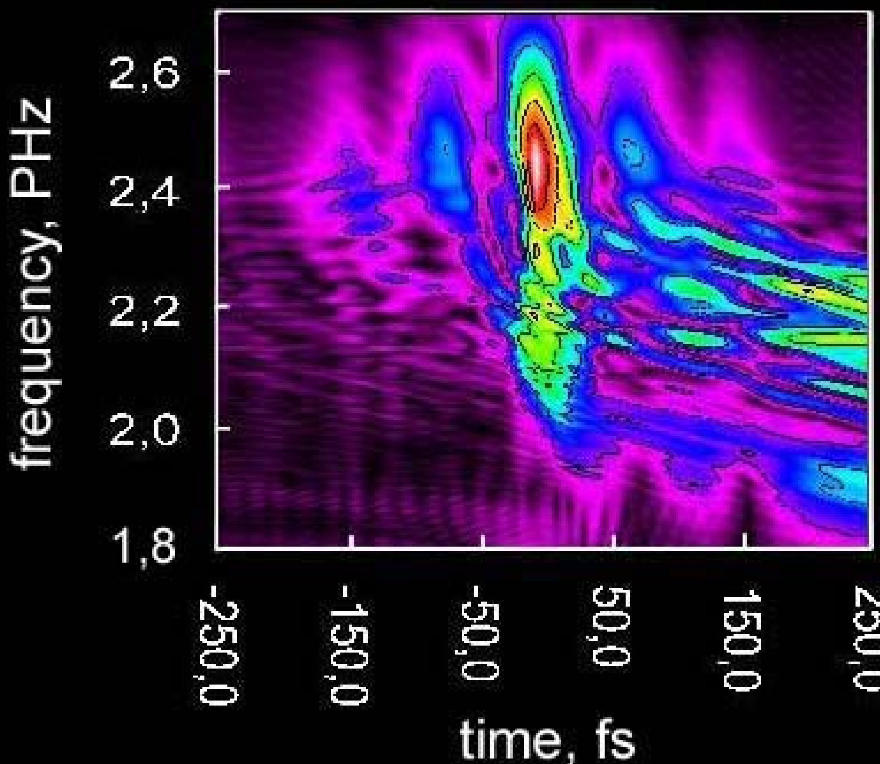
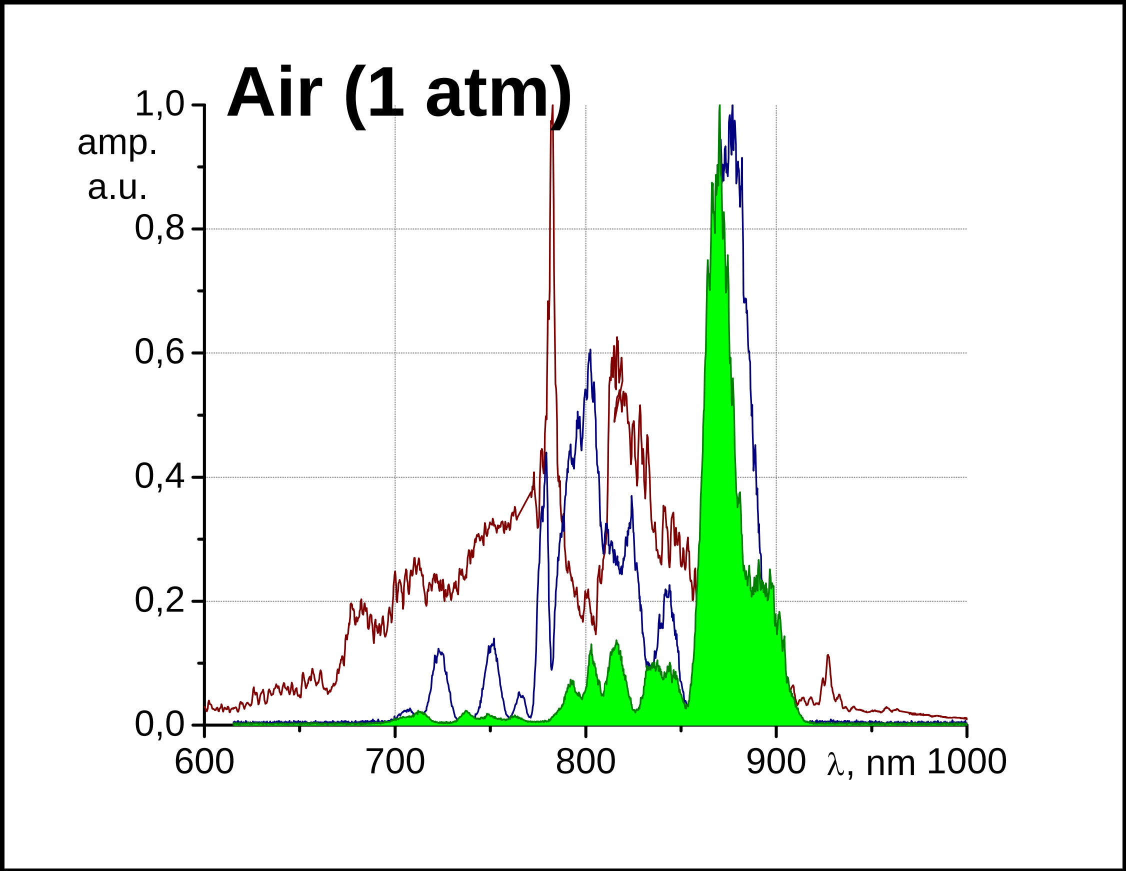


Pulse energy ~ 250 μJ

New spectral components generation due to Raman scattering and four-wave mixing



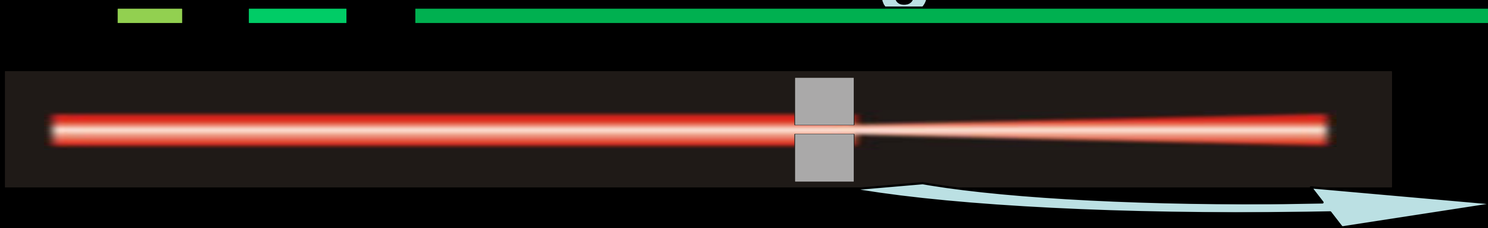
We investigate spectra peculiarities in dependence on:

- gas type and pressure
- distance along filament
- laser pulse chirp
- aperture size

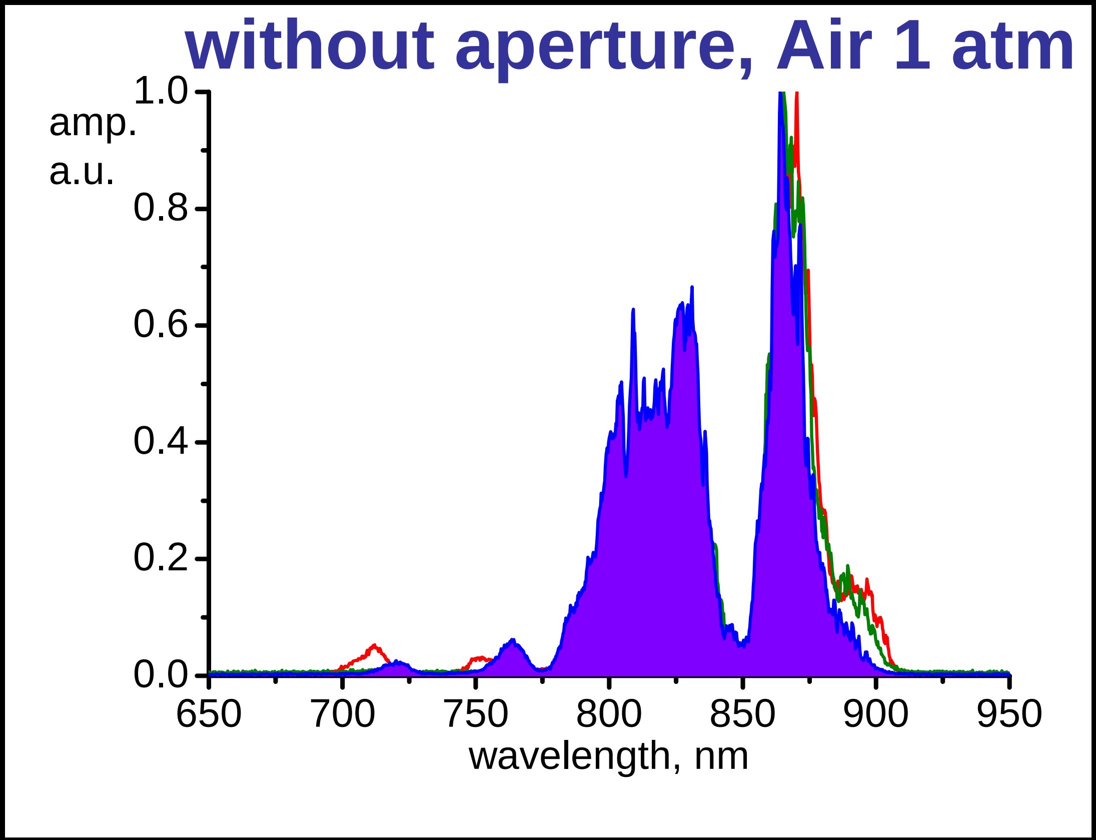
In nitrogen spectra of radiation has the similar envelope

The component appearance connected with Raman scattering

New spectral components generation due to Raman scattering and four-wave mixing



without aperture



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Raman spectral component propagates in the filament core

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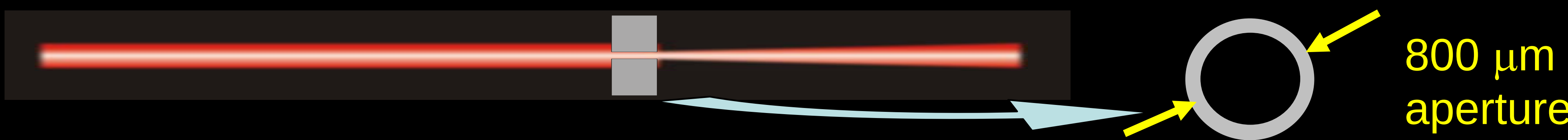

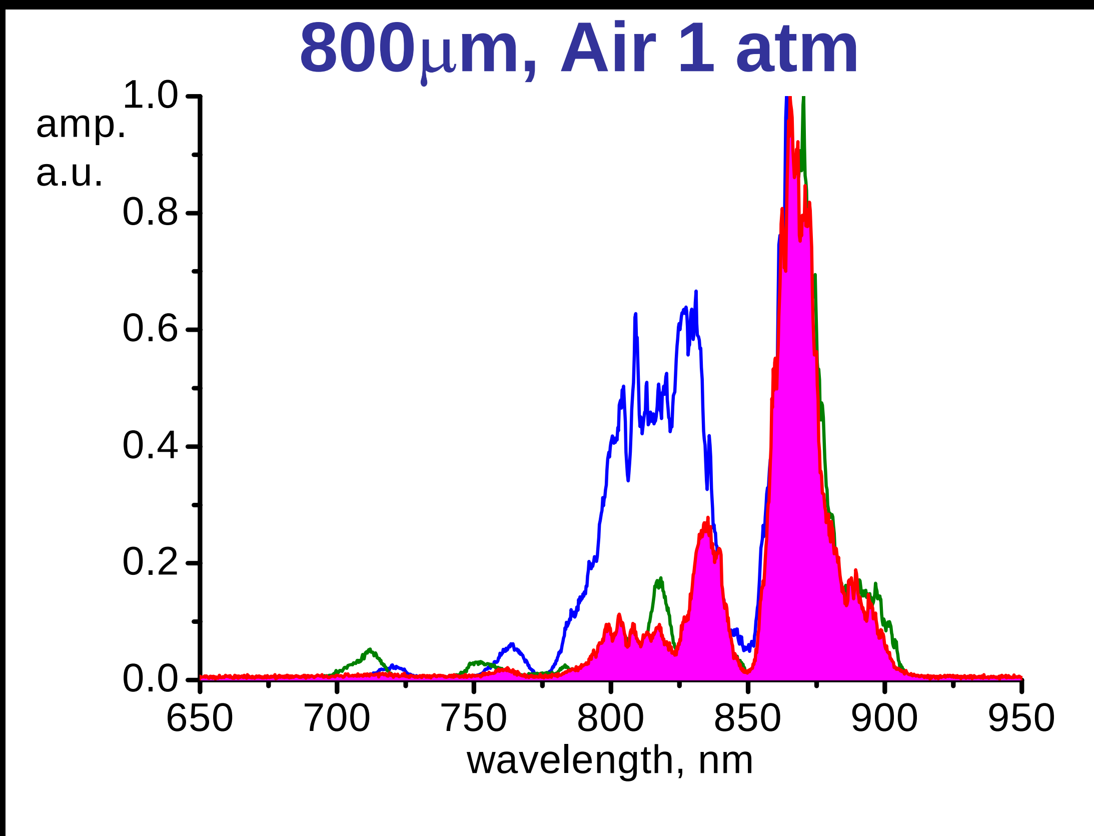

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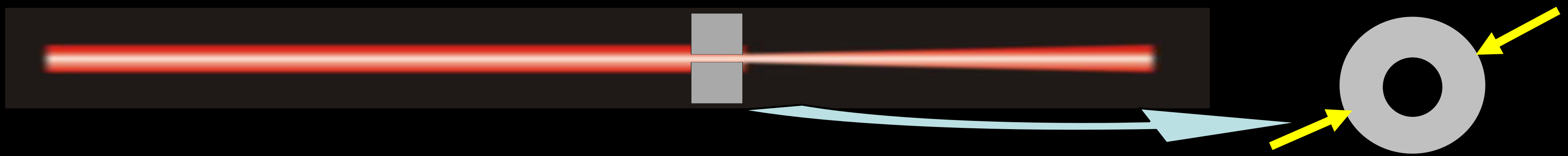

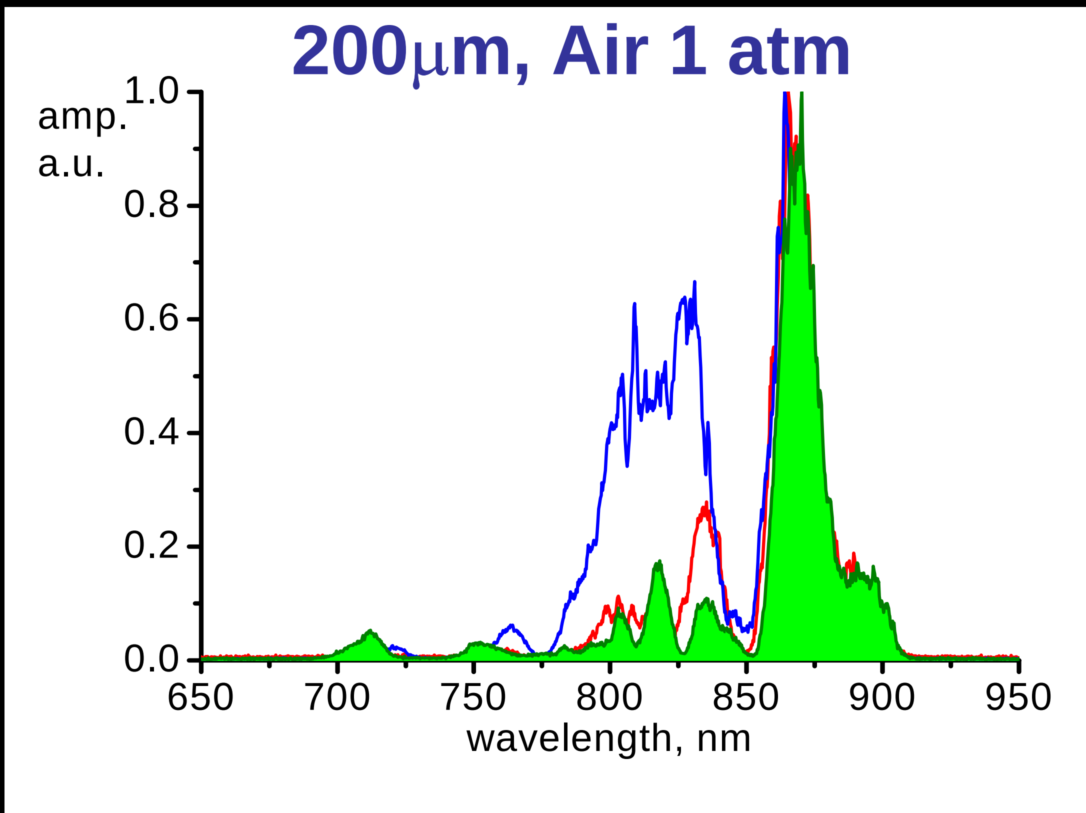

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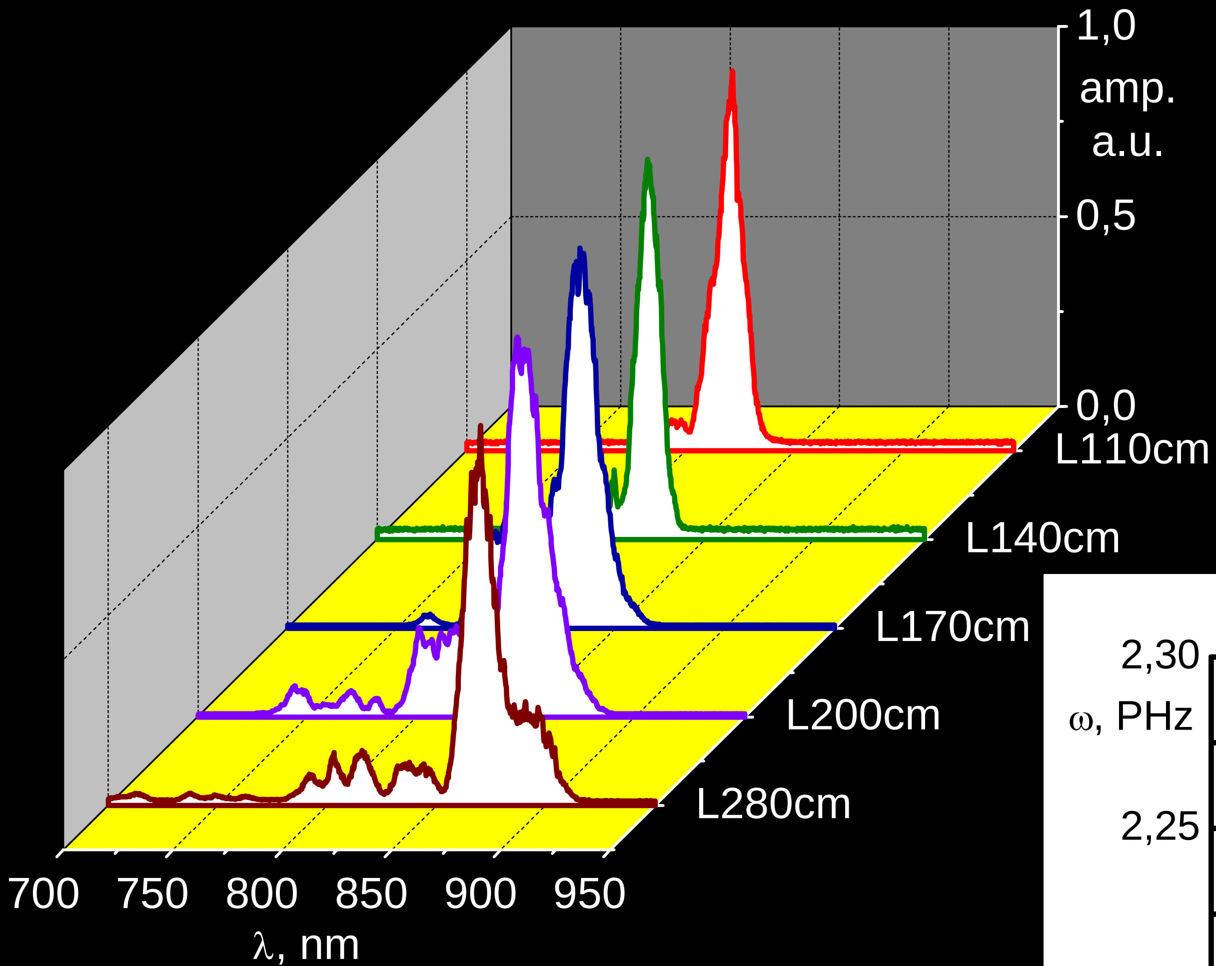
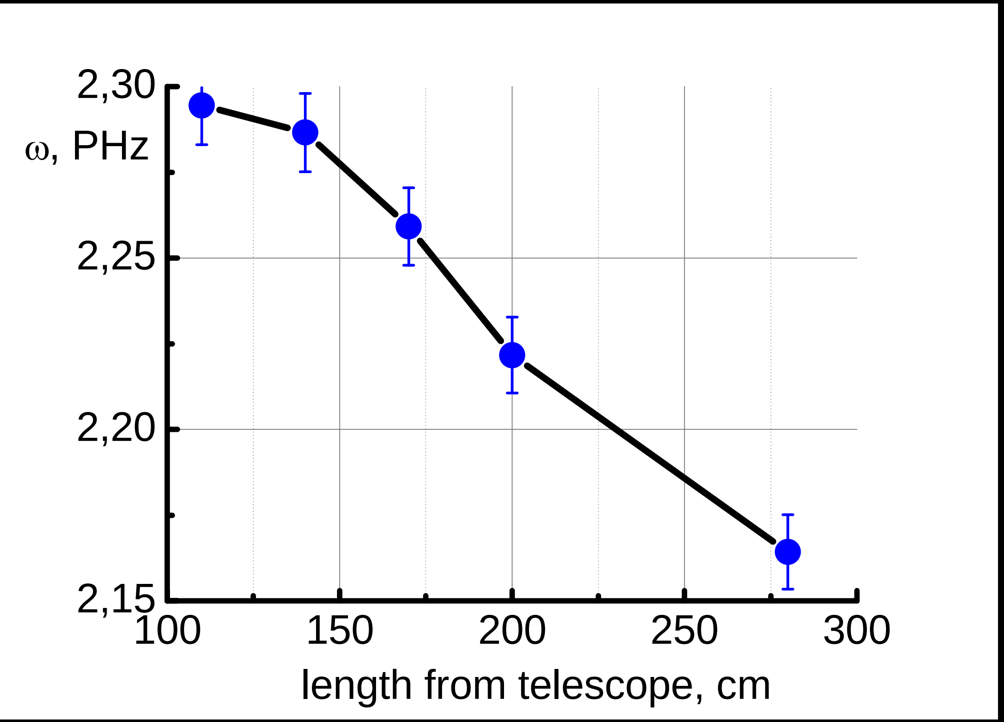
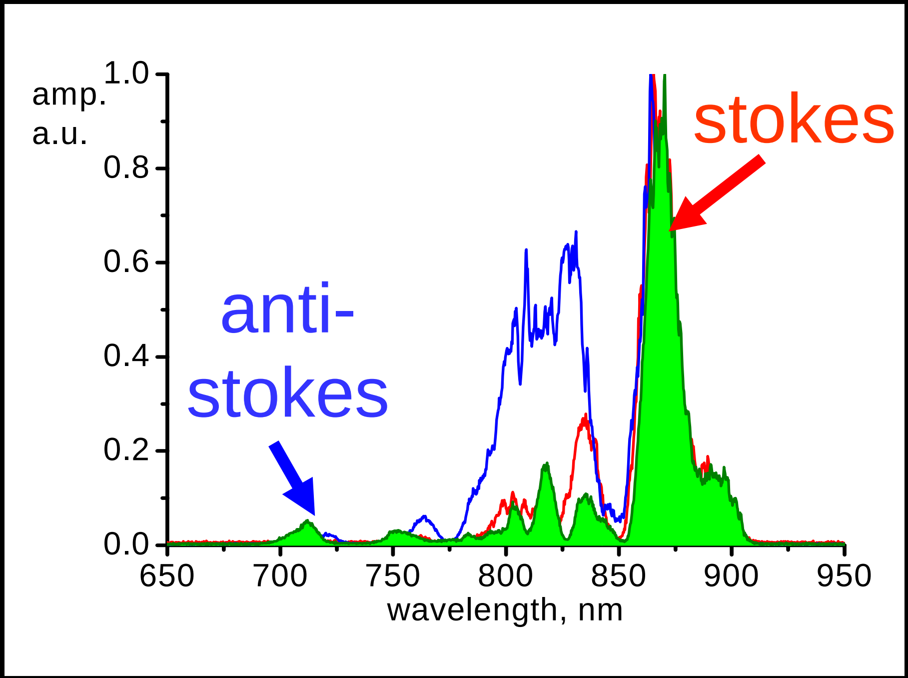


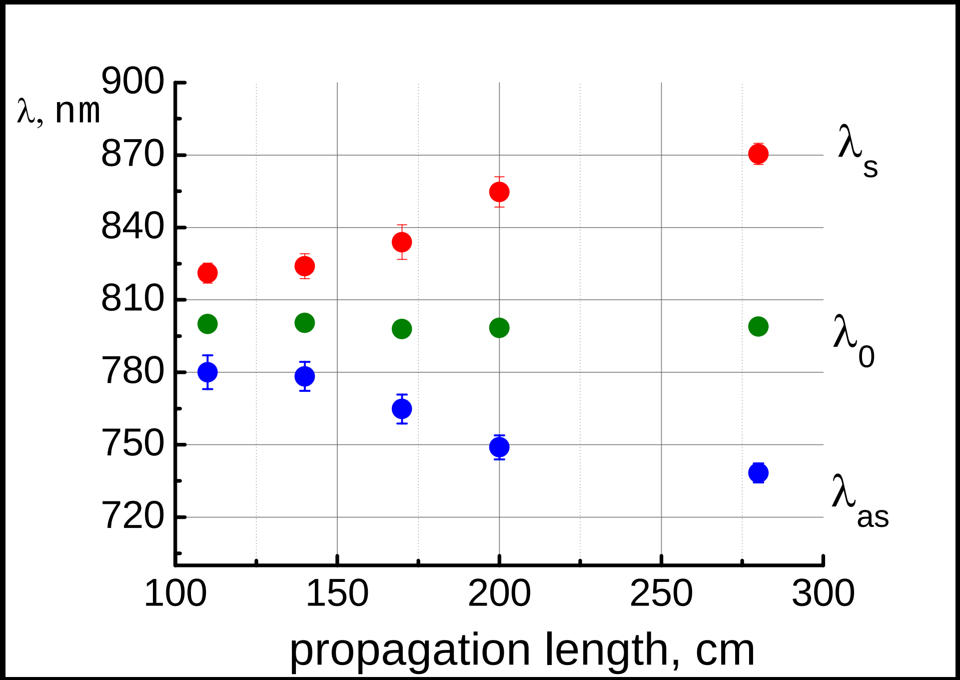


Central wavelength of Raman spectral component moves with distance along filament

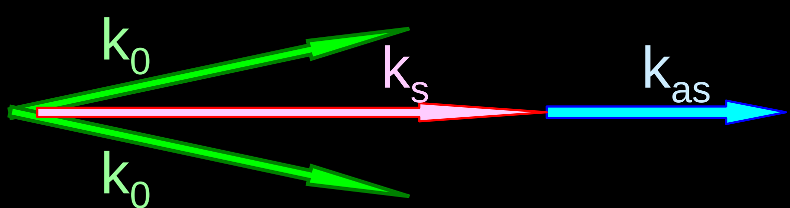
New spectral components generation due to Raman scattering and four-wave mixing

In several experiments together with Raman component we observed generation of the symmetrical (anti-stokes) spectral component





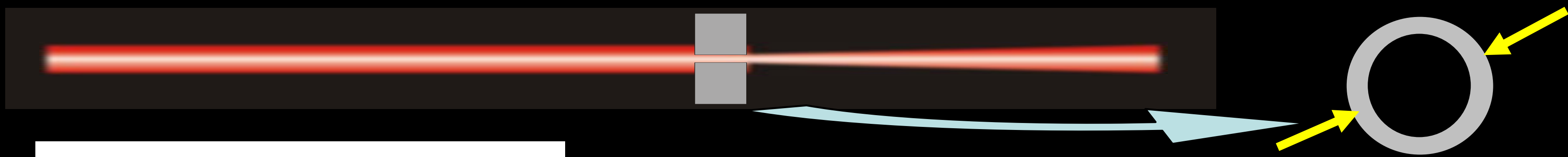
anti-stokes can be generated in each point of filament due to the next process:



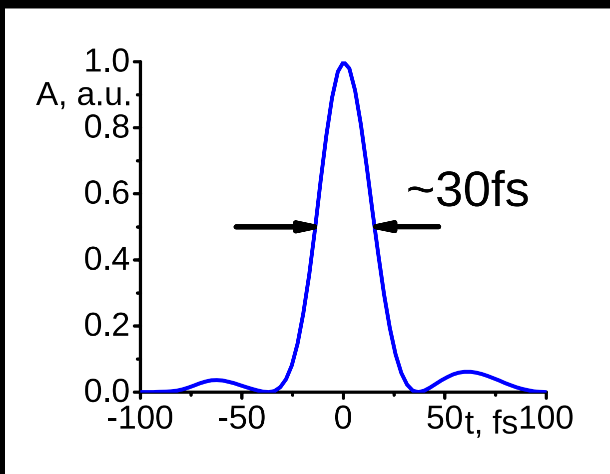
$$2\omega_0=\omega_s+\omega_{as}$$

$$2k_0=k_s+k_{as}$$

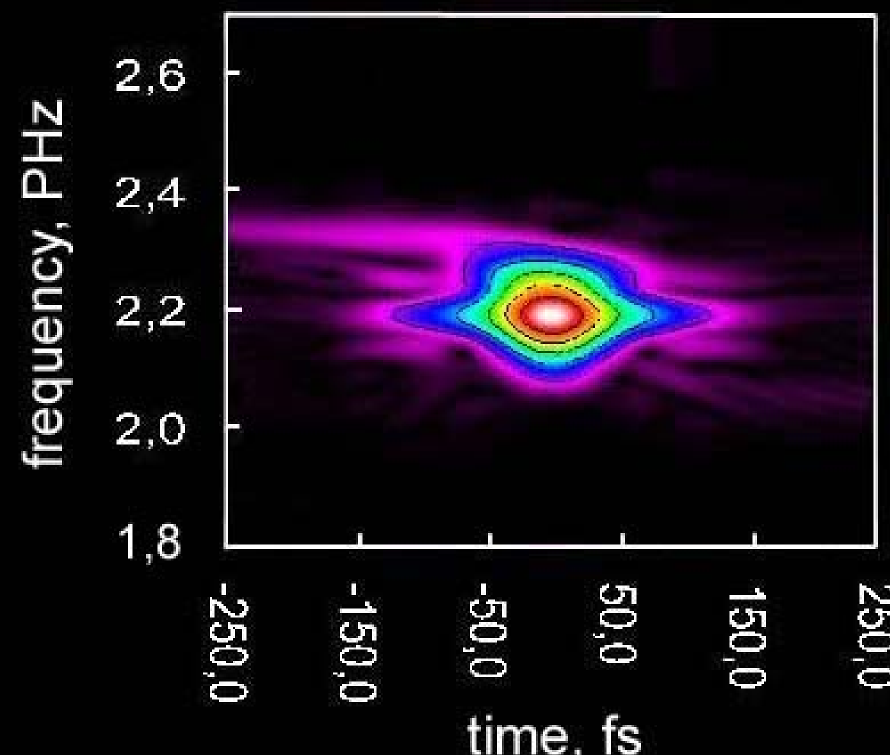
New spectral components generation due to Raman scattering and four-wave mixing

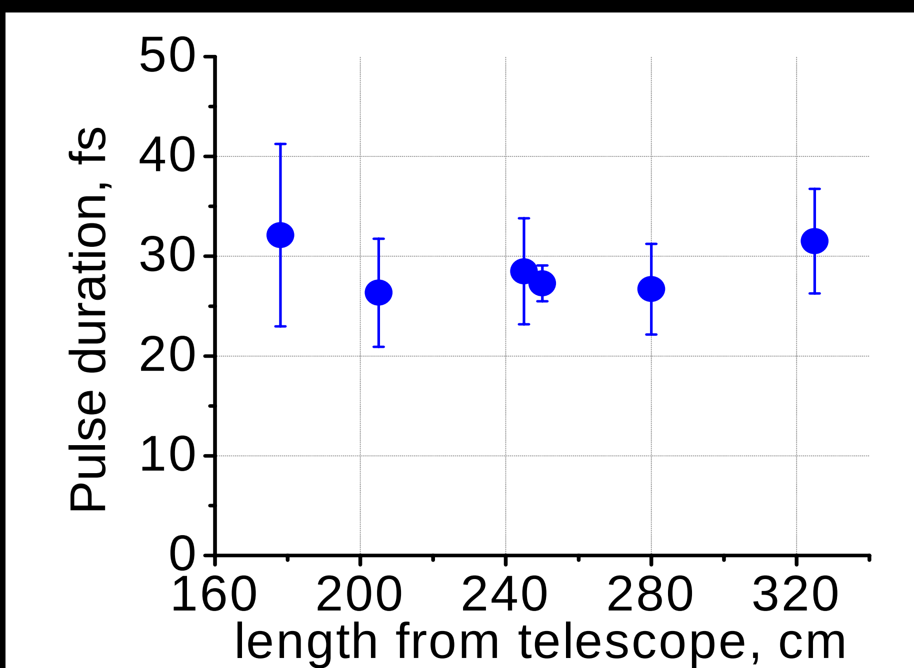


700 μm aperture



Air. P=1 atm. L = 285 cm





Pulse duration is not changed along filament

Conclusions

• Our study demonstrates that under filamentation of collimated beam in argon one can obtain very stable self-compressed laser pulse with essential suppression pre- and post- pulses. Nearly fivefold compression of 55fs laser pulse was achieved in about 90% of laser shorts.

• Diameter of extracting aperture substantially determines compressed pulse duration. In aperture with diameter 700μm minimal pulse duration is 12fs, while in 300μm aperture pulse duration is 8fs.

• Under filamentation in molecular gases (air, nitrogen) new bright spectral component appears due to Raman scattering. This component propagates in the filament core. Its duration is about 30fs and is not changed along filament. Central wavelength of this component moves with the distance along filament.