B.I.Stepanov Institute of Physics

FEMTOSECOND RAMAN AMPLIFICATION

IN CRYSTAL MEDIUM

Minsk

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Content

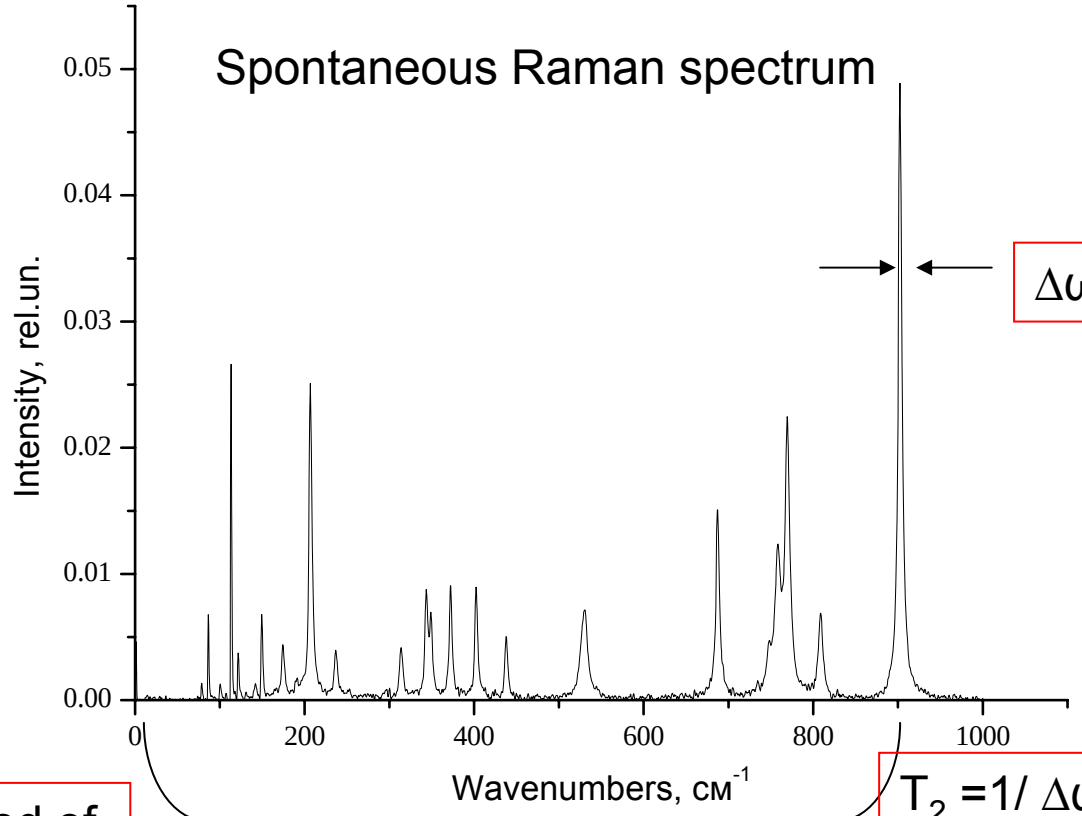
Introduction:
what is Raman amplification at fs pumping?

Conditions of experiment

Results and discussion

Conclusion

Basic notions



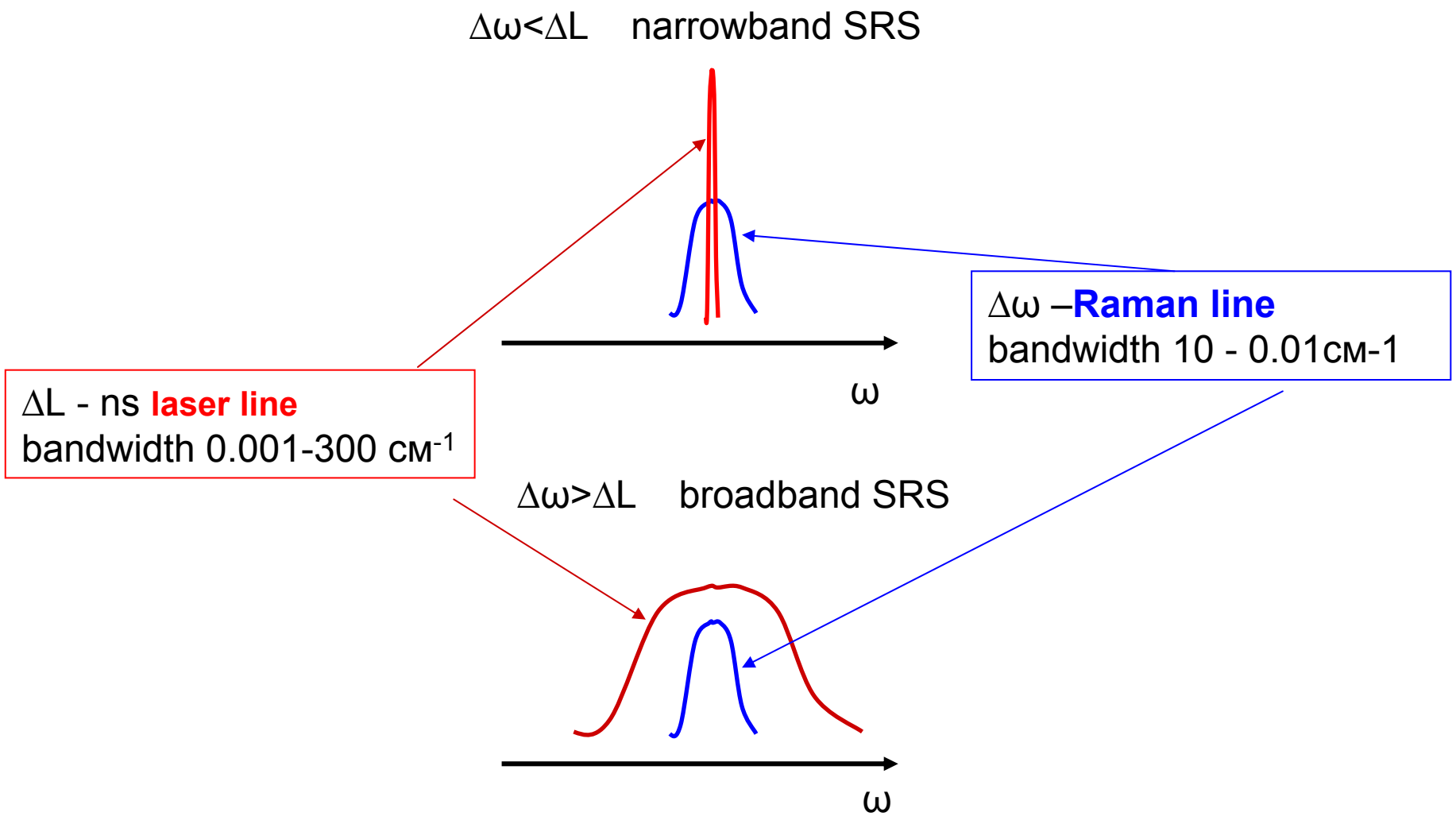
$\Delta\omega$ –line bandwidth

$T_2 = 1/\Delta\omega$
coherence dephasing time

$T_{vibr} = 1/\Omega$ - period of molecular vibrations
< 100 фс

Ω – wavenumber of molecular vibrations

Raman amplification



Transient and impulsive SRS

Transient conditions

$t_{pulse} < |g|/T_2$

Laser pulses shorter than T_2

decrease of Raman amplification

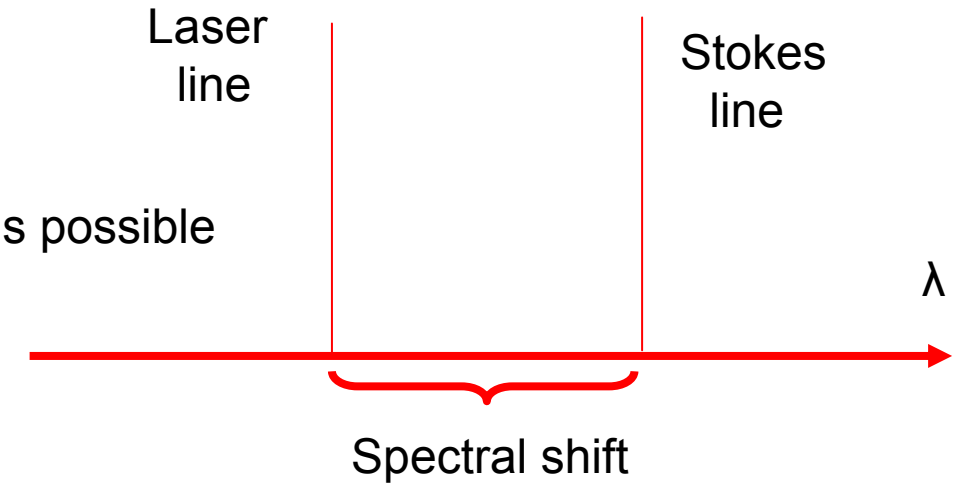
Impulsive (super-transient) conditions

$t_{pulse} < T_v = 2\pi\Omega_v^{-1}$

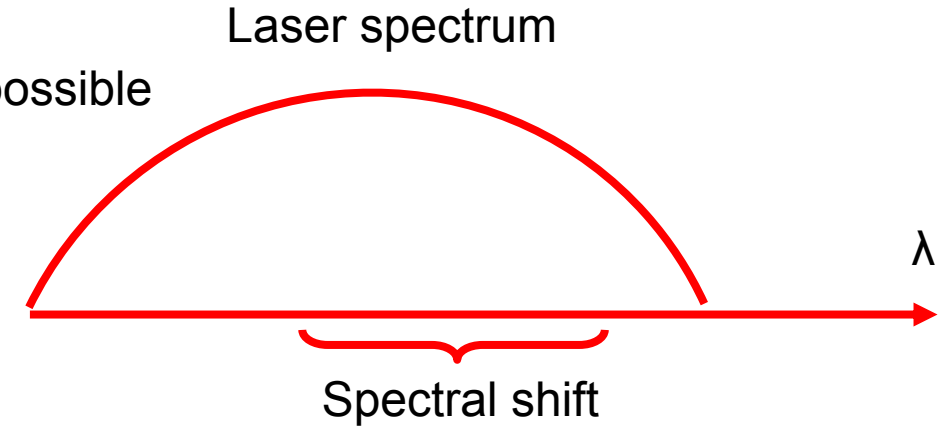
Pump pulse is shorter than molecular vibration period T_v

Traditional SRS and impulsive SRS
Spectral presentation

Traditional SRS
Spectral separation is possible



Impulsive SRS
Spectral separation is not possible



Problems in the transient and impulsive regimes

- Decrease of Raman gain due to transience
- Competition with other nonlinear optical effects due to high intensity of fs pulses
- Difference in group velocities for laser and Stokes pulses due to dispersion
- Overlapping pump and Stokes spectrums

Aims of experiment

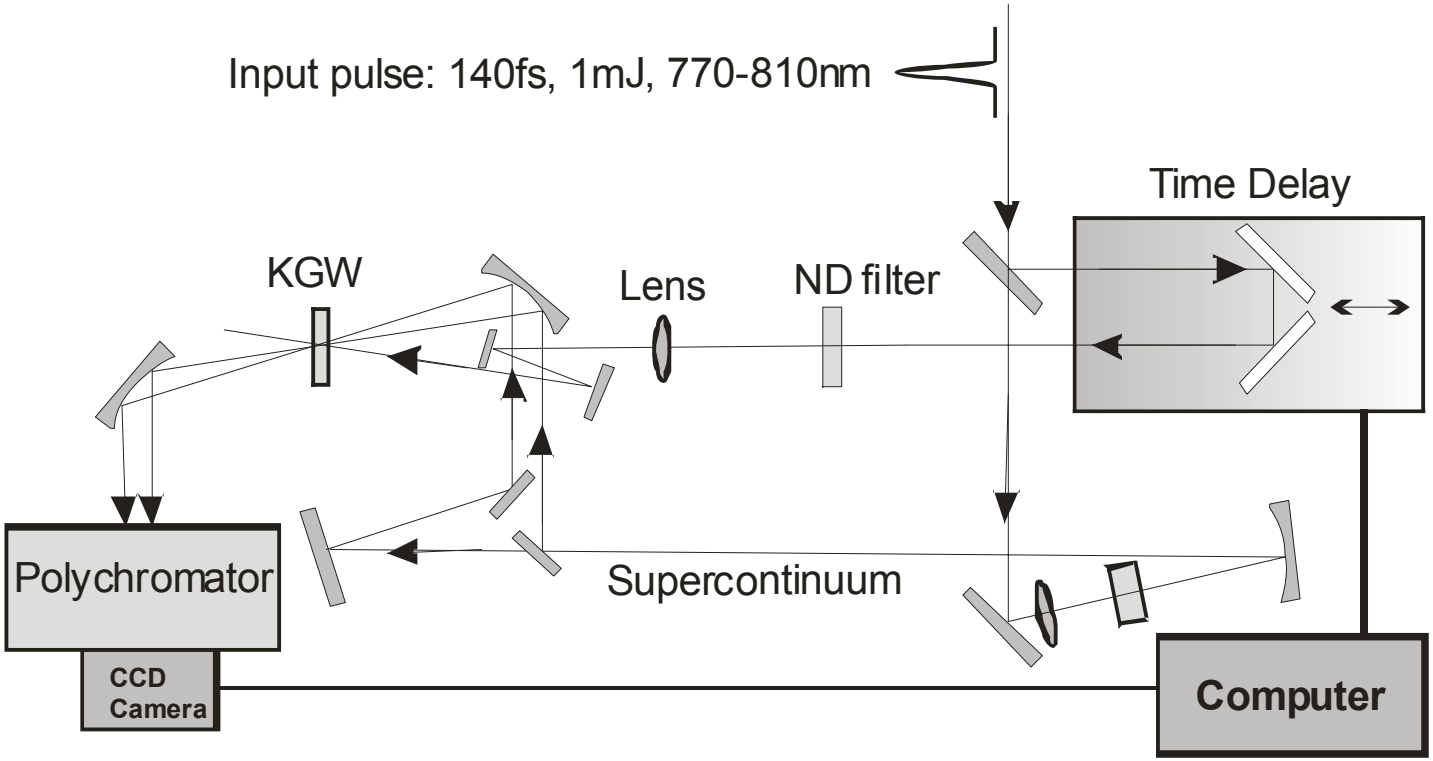
To understand: what is SRS at femtosecond pumping?

To support a possibility to obtain Raman amplification in crystals with minimization of competition with other effects ?

To investigate main regularities of Raman amplification in such conditions

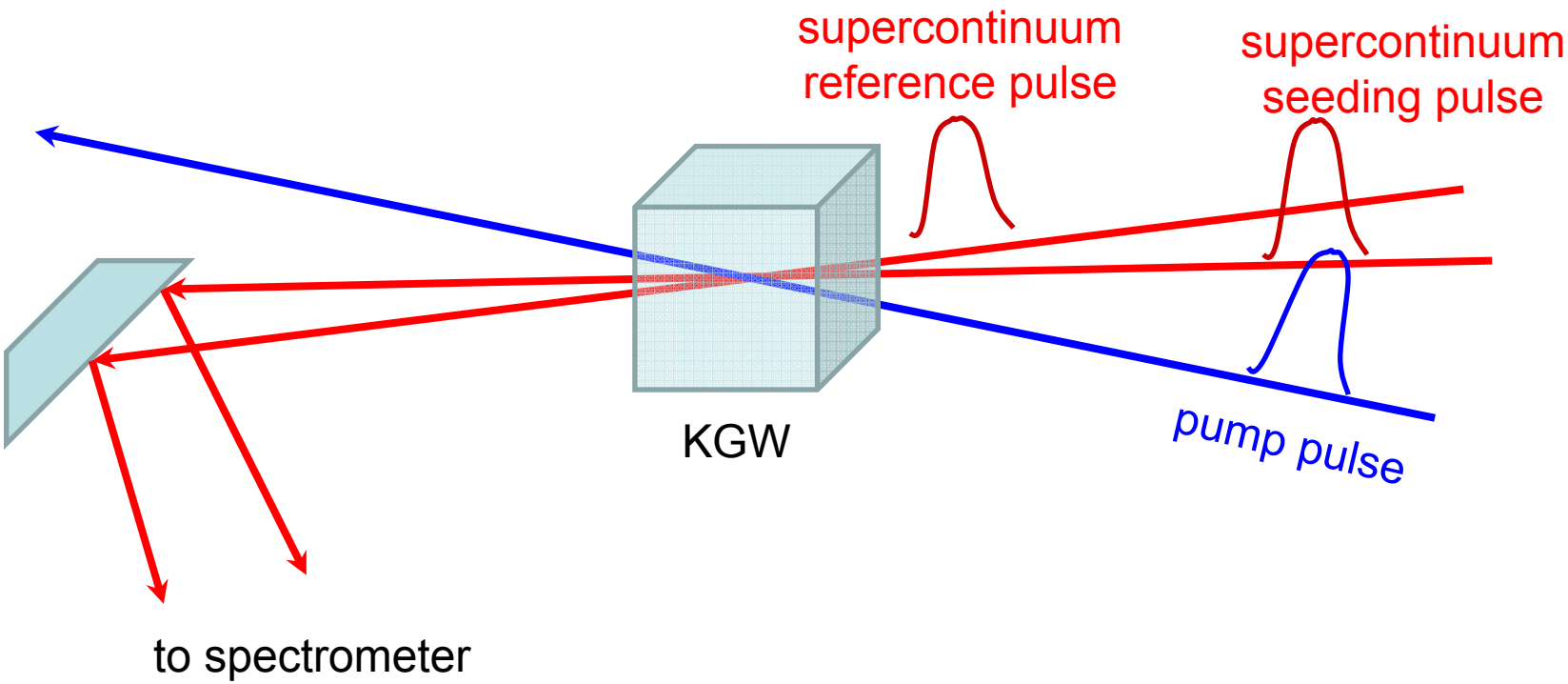
Aproach –
investigations at decreased intensities under Raman threshold

Experimental set-up



Center of femtosecond pulse spectrum is at 810 nm.
Stokes seed pulses – pulses of supercontinuum (380-1100 nm)

Scheme of experiment



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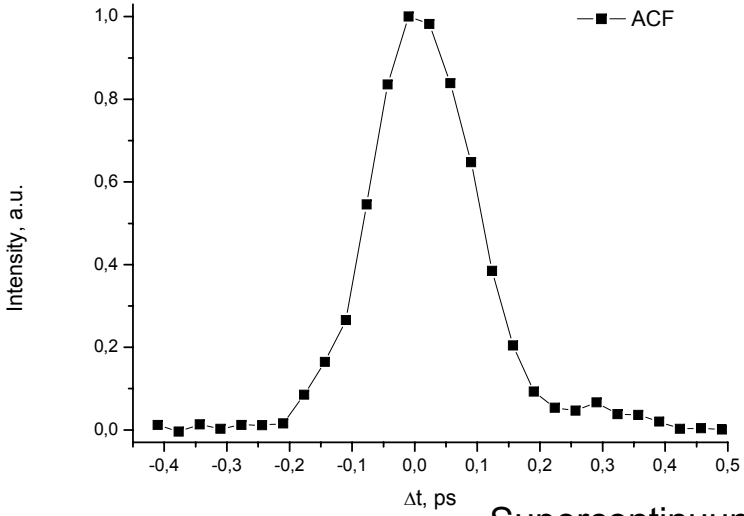
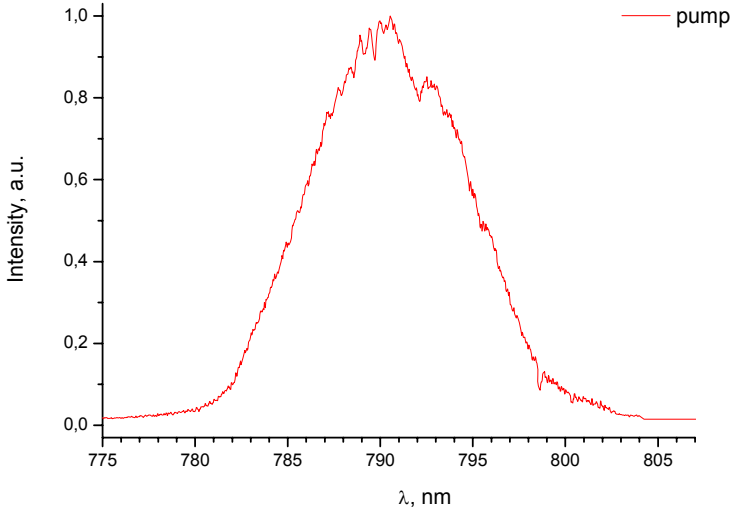
Autocorrelation function of pump

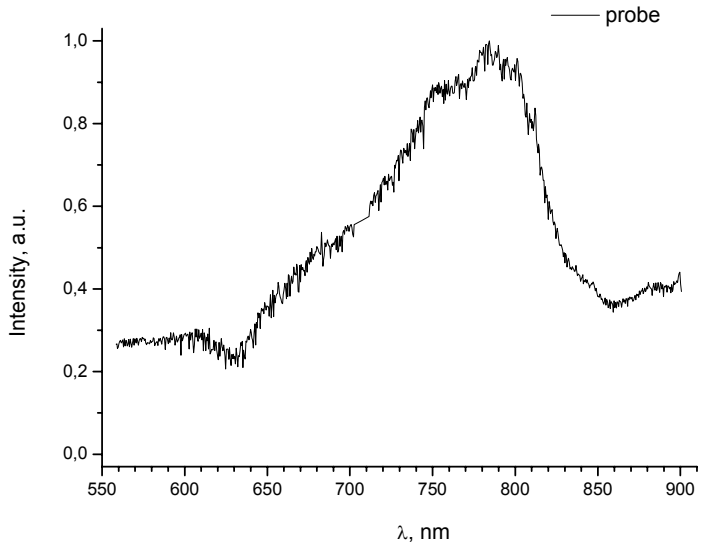
τ=150fs $\tau \times \Delta\upsilon$=0.7 ($\tau_{min}$=77fs)



Pump spectrum $\Delta\lambda$=10nm

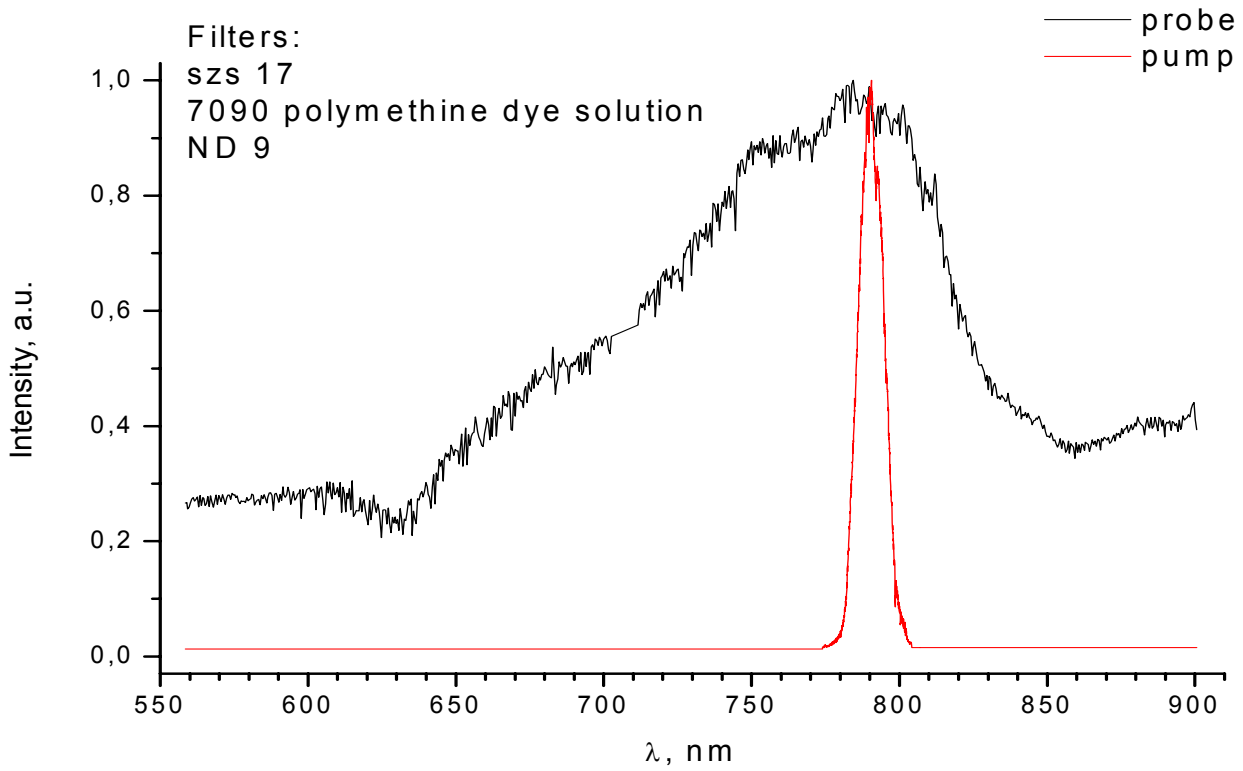


Supercontinuum spectrum



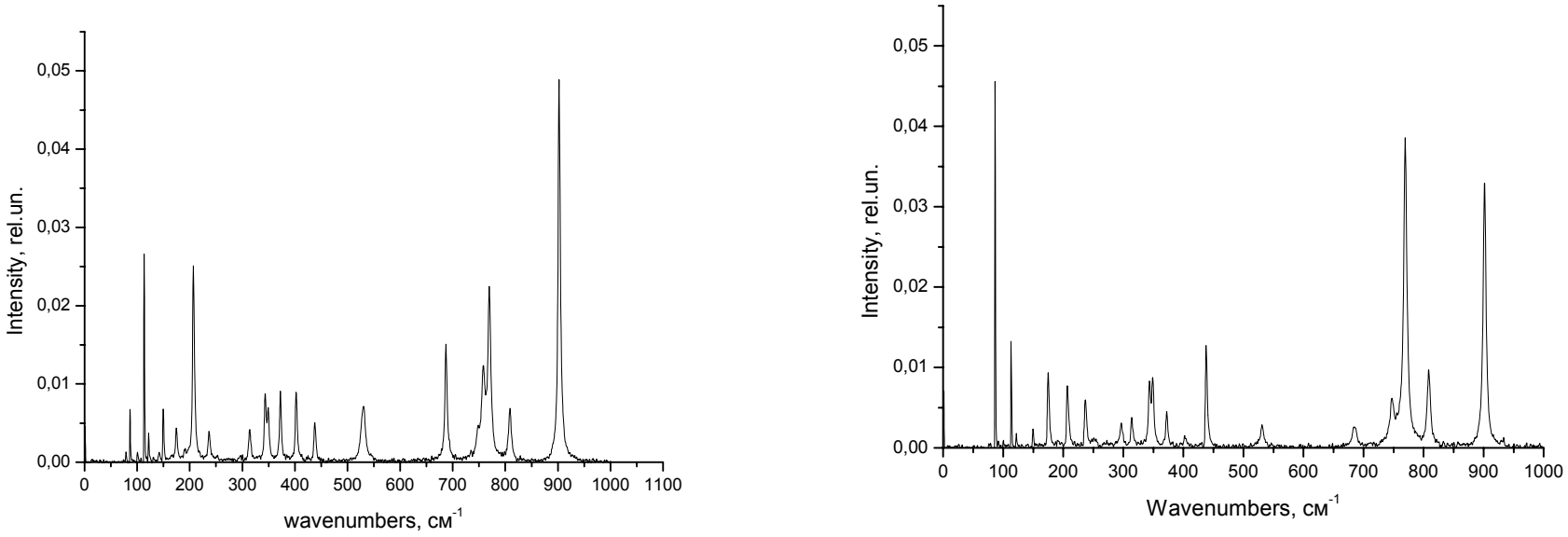
380-1100 nm

Spectral properties of pulses at the input of Raman amplifier



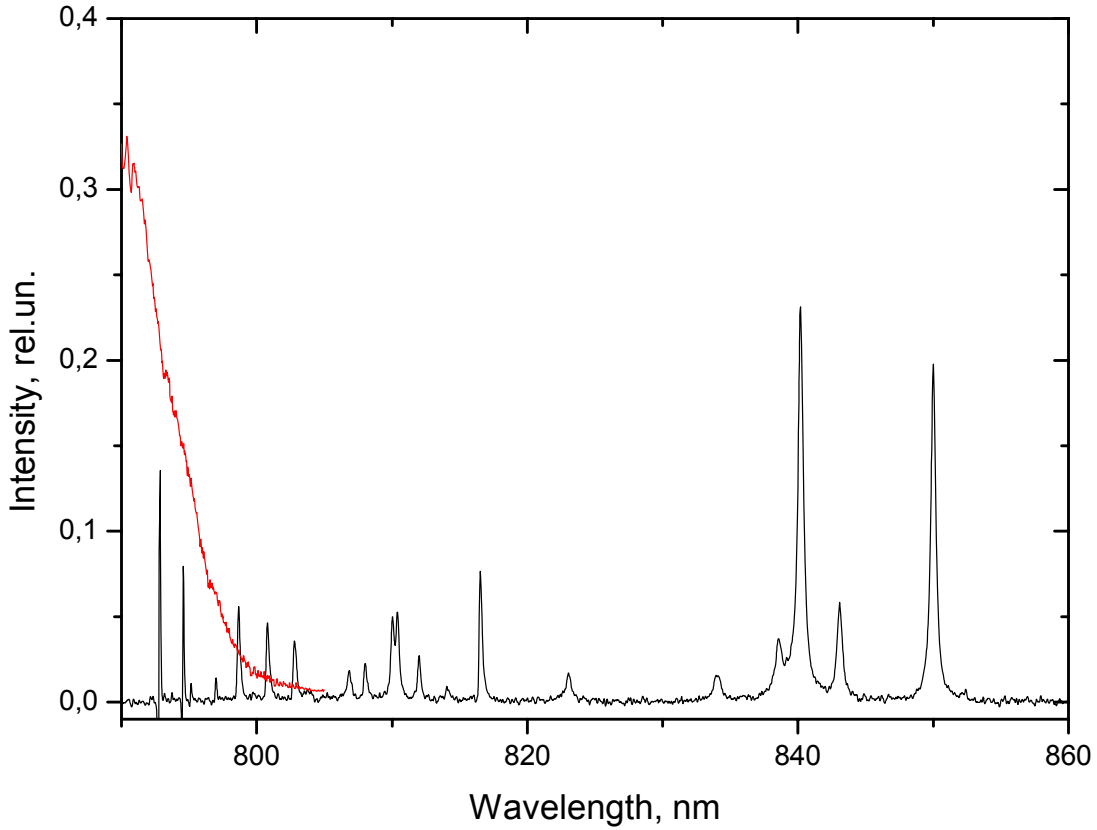
Raman medium – KGW crystal

Length of KGW – 4 mm, two-axis, birefringent medium
Strongest Raman line - 901 см-1,
Dephasing time of molecular vibrations - 2 ps,
Regime of scattering - transient.

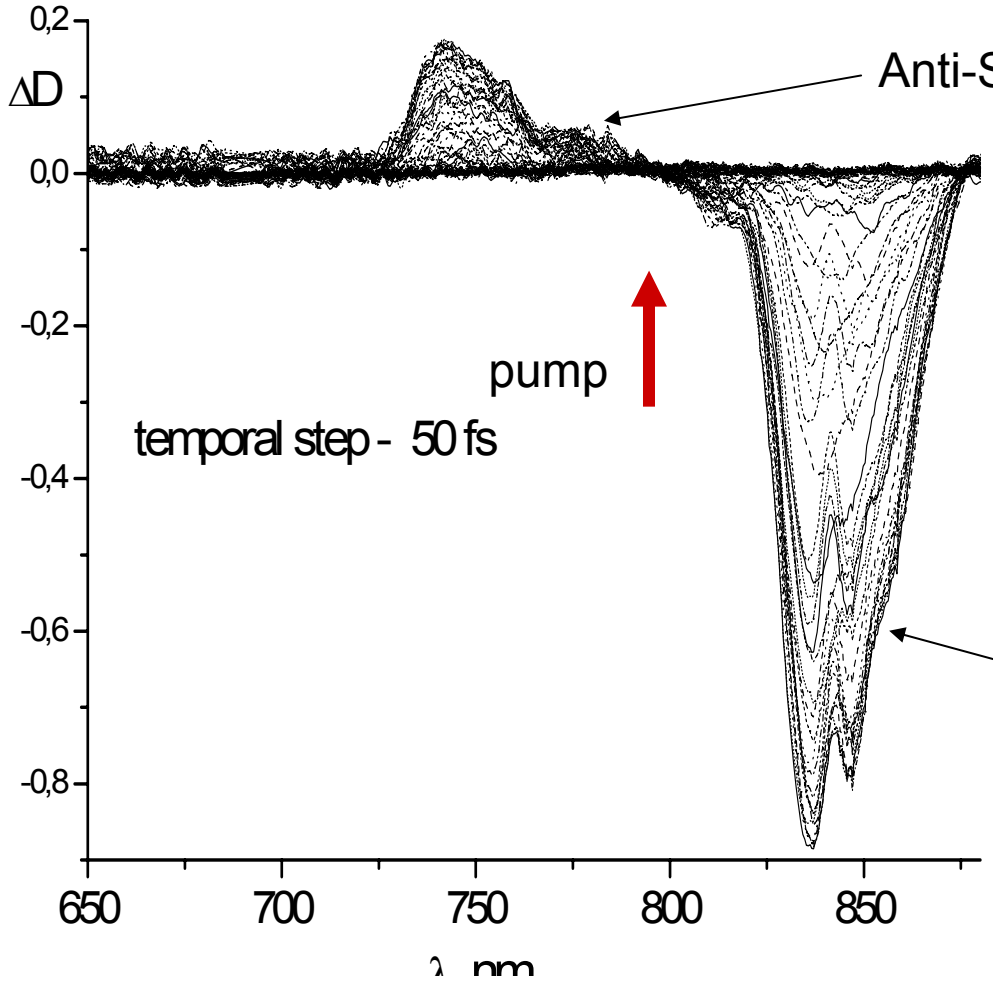


Spectrums of spontaneous Raman scattering
for two perpendicular orientations of KGW crystal: anisotropy effect

Comparison of pump spectrum and spontaneous Raman spectrum. Impulsive effect



Raman amplification – general picture of measurement

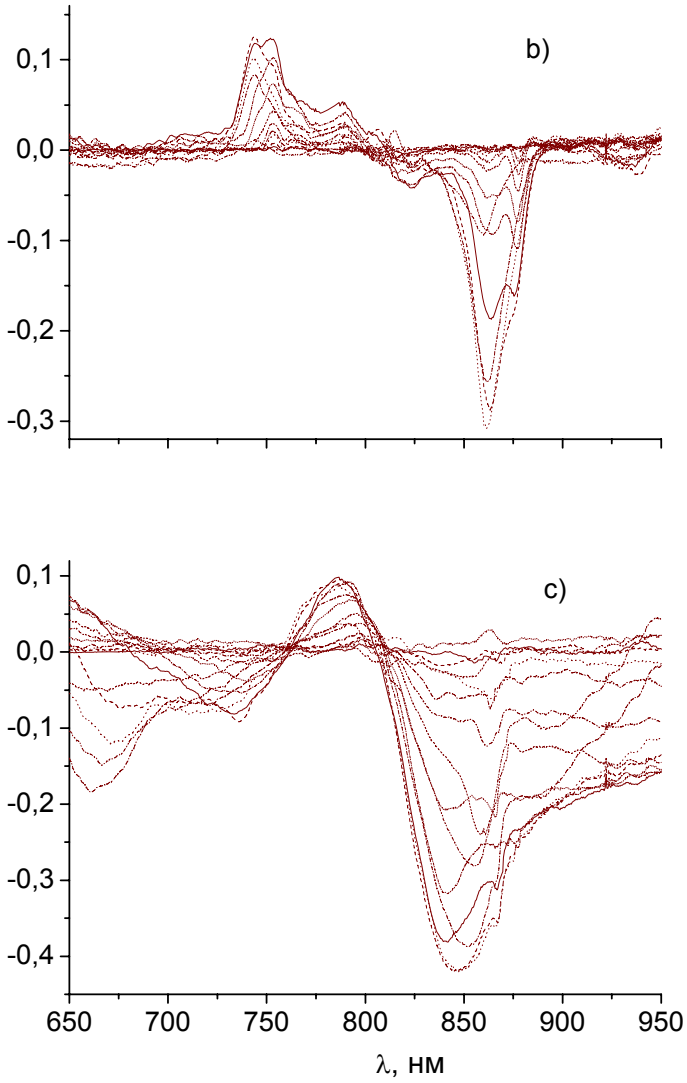


Transient spectra

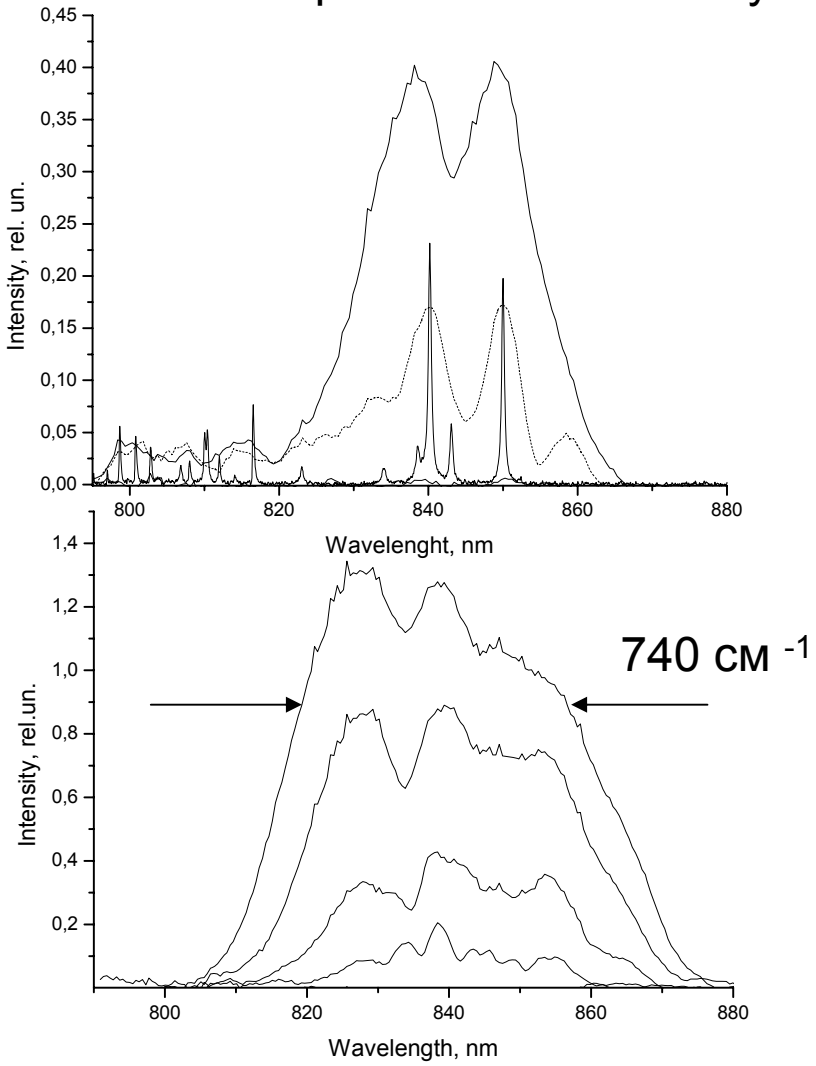
$$\Delta D(\lambda, t) = \lg(T_0 / T)$$

$T = I_{prob}/I_{ref}$ $T_0 = I_{0prob}/I_{0ref}$.

Raman amplification – Kerr-effect influence

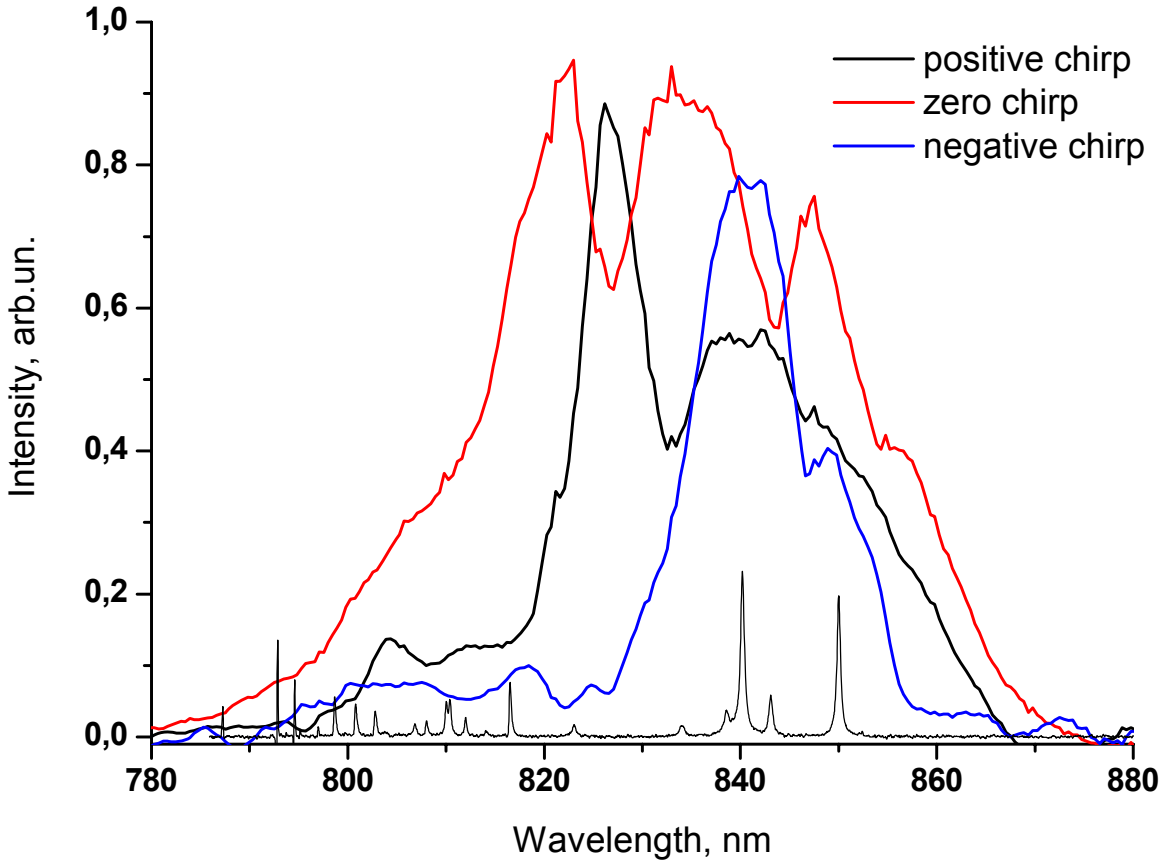


Raman amplification in KGW crystal

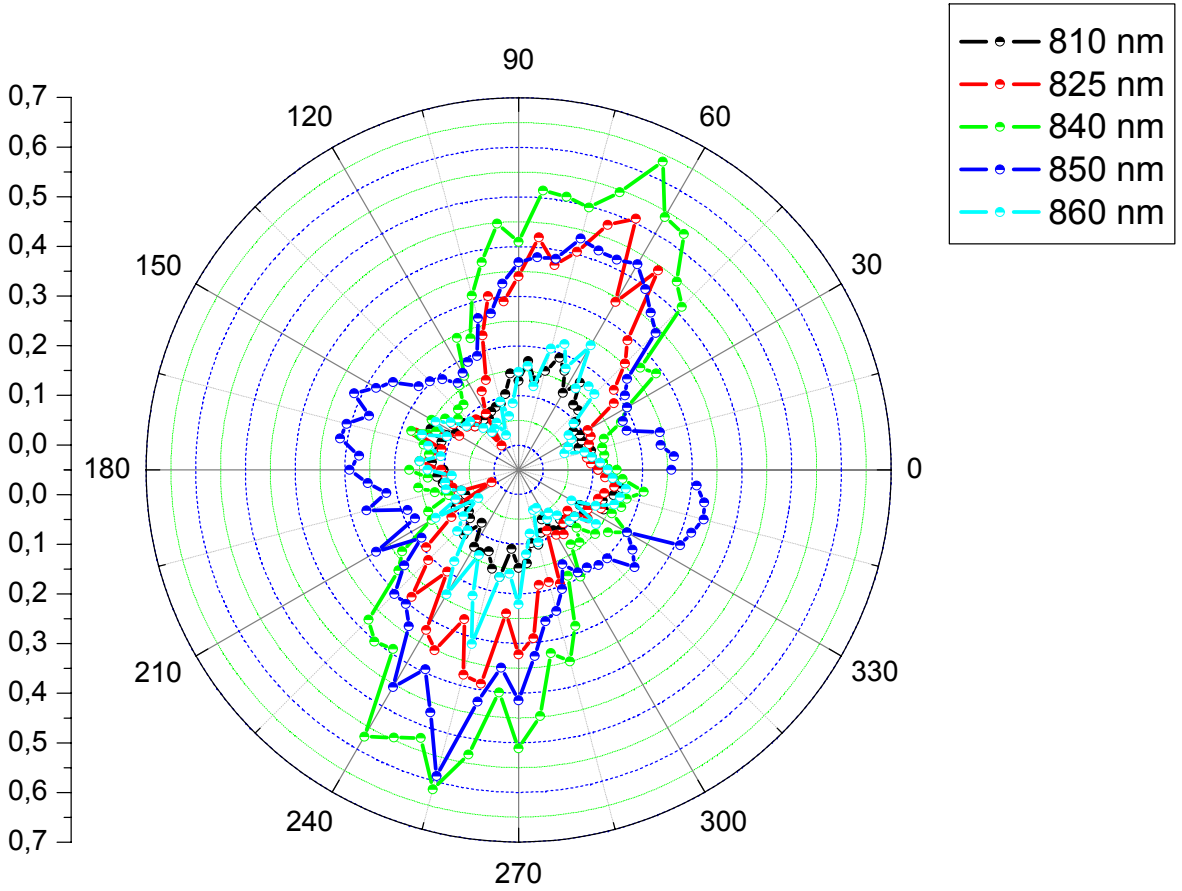


Comparing the development of Raman amplification spectrum and spontaneous Raman spectrum(left). Development of amplification spectrum with maximal bandwidth registered in experiment (right), Maximal signal corresponds to overlap of pump and seed pulses.

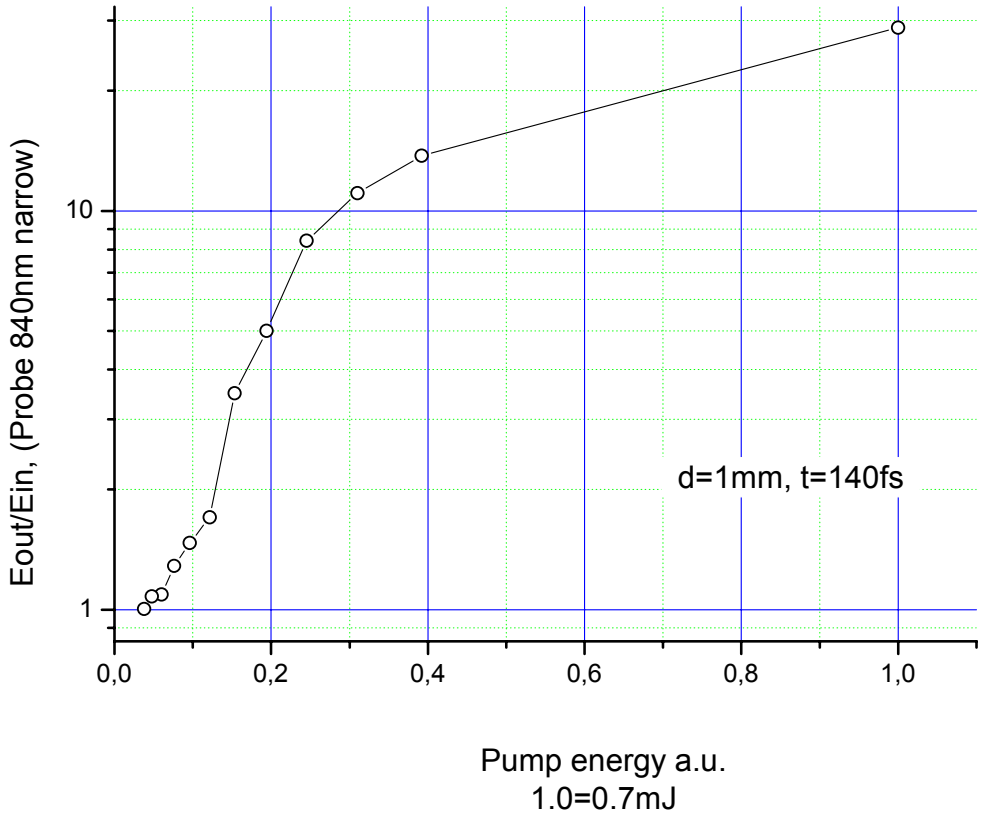
Pump chirp effect



Crystal orientation effect (anisotropy)



Raman amplification measurements



Discussion

Observed -

formation of super-broad Raman amplification band
740 см$^{-1}$ at half-maximum (more than 850 см$^{-1}$ on background)
at corresponding pump bandwidth of 130 см$^{-1}$

Possible reasons:

- Raman amplification at different Raman active vibrations,
- Spectrally broadband pump
- Kerr effect

Conclusions

Raman amplification in crystal medium at femtosecond pumping is demonstrated

Formation of Raman bandwidth strongly exceeding the pump bandwidth is observed

For the first time participation of many Raman active vibrations in creation of Raman amplification bandwidth is shown

Thanks for attention