LIGHT PULSE STRUCTURE, SPECTRUM AND COHERENCY OF NOVOSIBIRSK TERAHERTZ FREE ELECTRON LASER

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  - spectral width and detuning of electron frequency
  - three spectral regimes of NovoFEL
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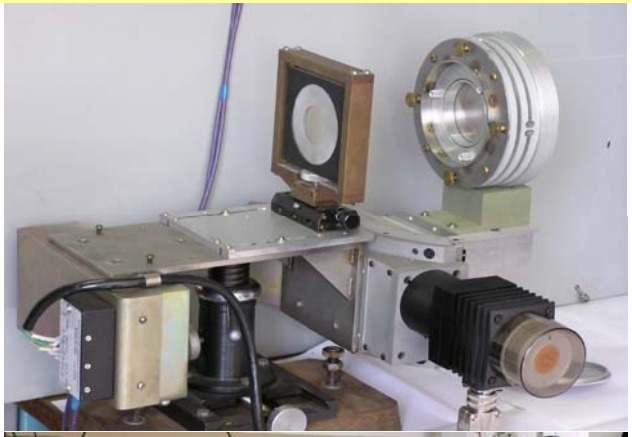
  - coherency and harmonic generation
- Conclusion

Spectral devices of Novosibirsk FEL



Mesh Fabry-Perot interferometer:

a) high spectral resolution

b) compactness and simplicity

Upgraded grating optical monochromator:

a) wide spectral range of 0.3 - 300 μm

b) real harmonic separation for on-line adjustment and user's applications

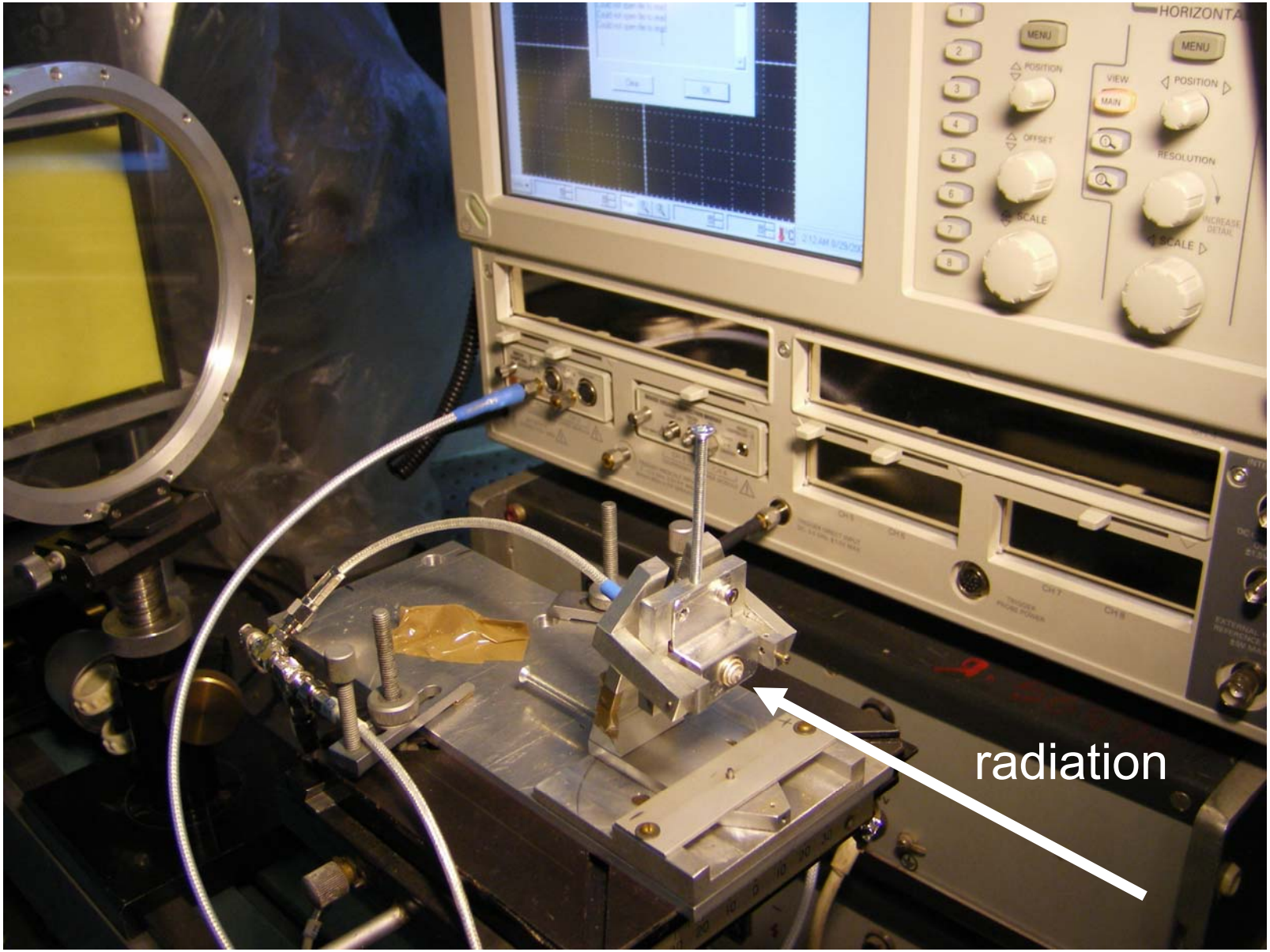
Bruker vacuum Fourier spectrometer IFS-66v:

a) clear vacuum spectrums

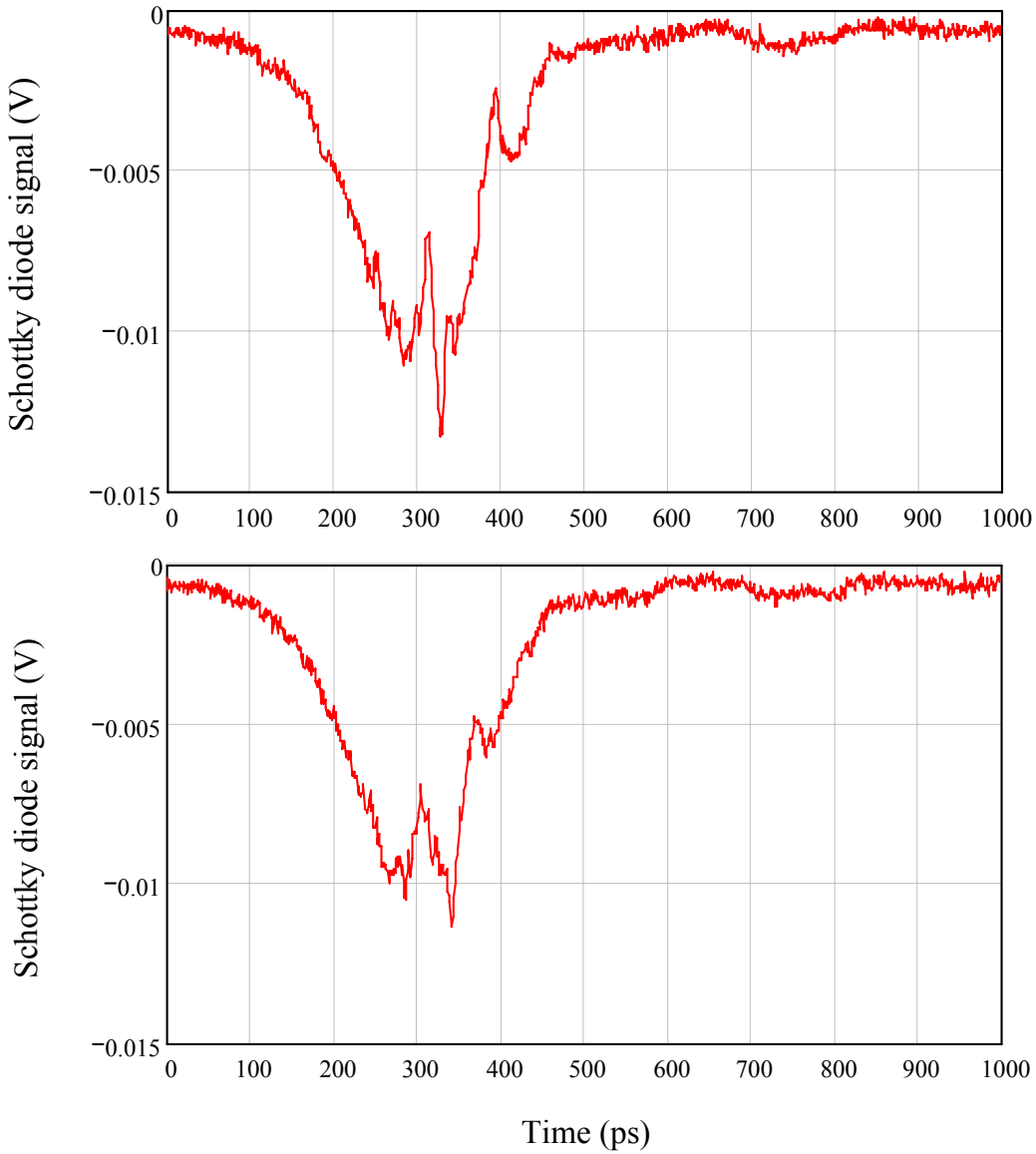
b) wide spectral range of 1-1000 μm

c) autocorrelation function (interferogram)

Ultra-fast Schottky diode detector



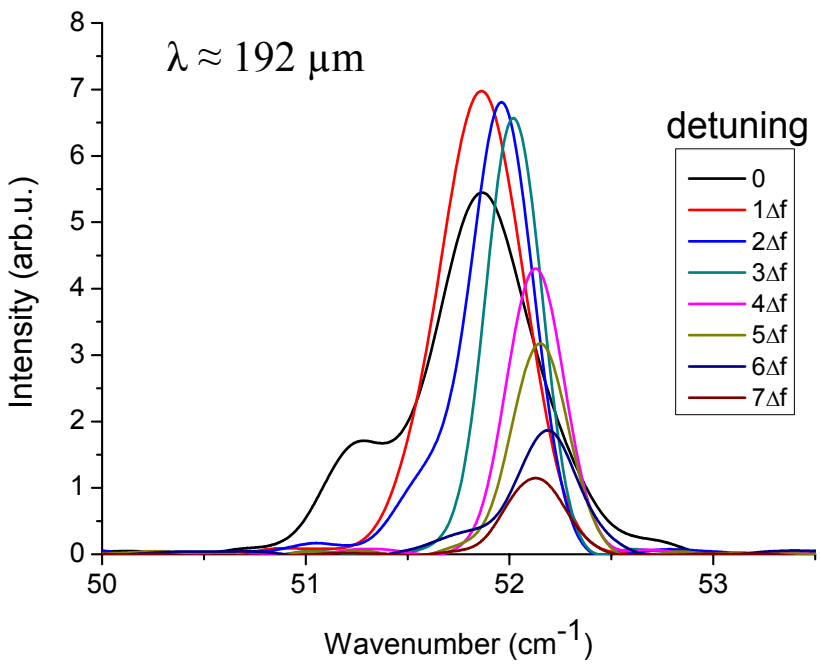
Rise time of Schottky diode and Tektronix sampling oscilloscope

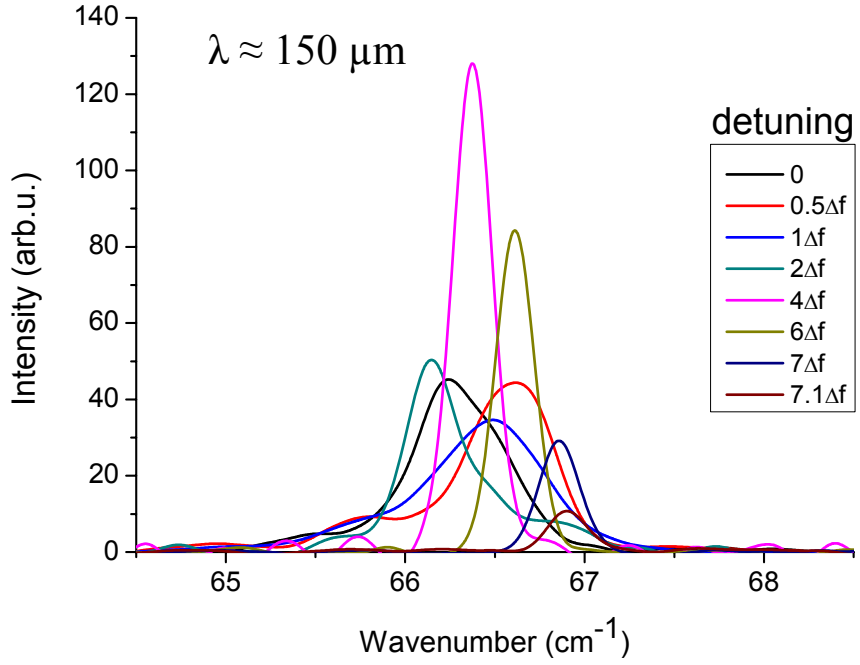


τ = 20 - 30 ps

Tektronix rise time: 18 ps

Spectrum versus detuning of electron beam frequency

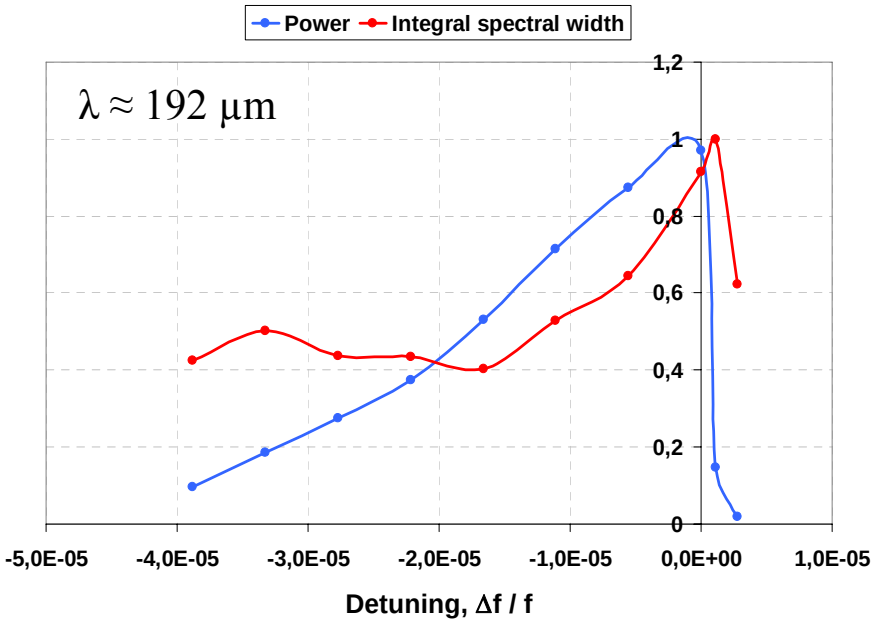


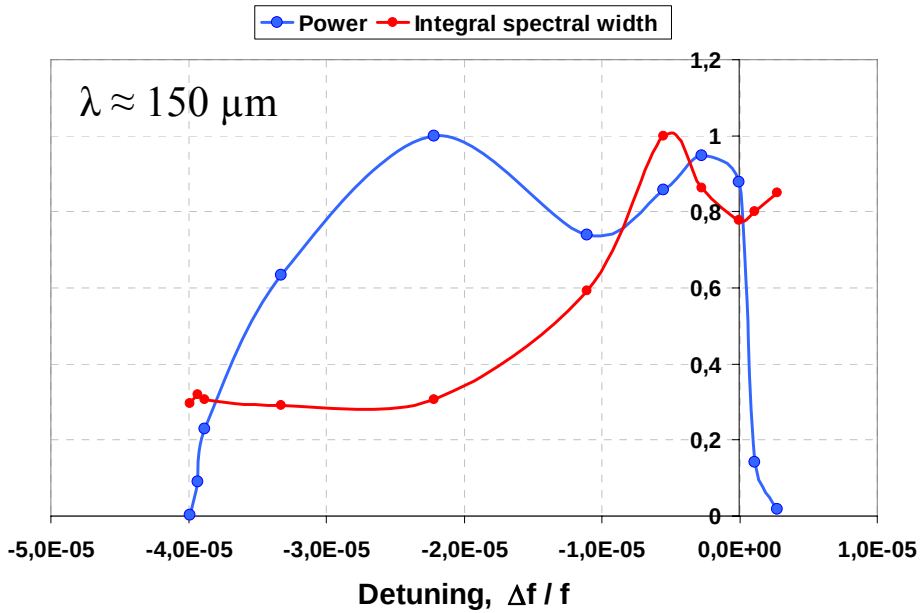


$\Delta f / f = - 5.543 \cdot 10^{-6}$

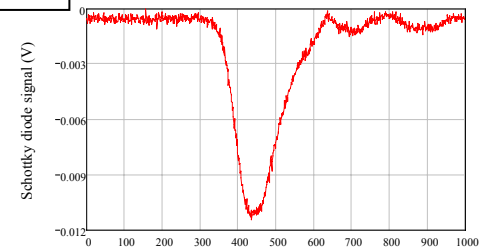
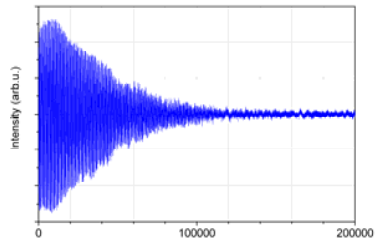
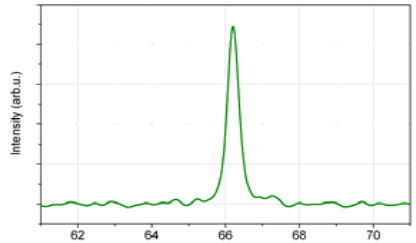
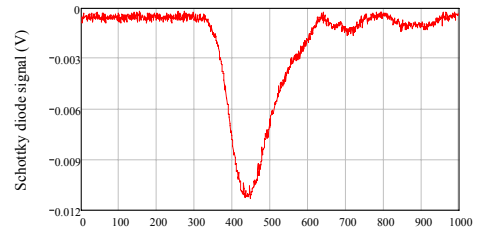
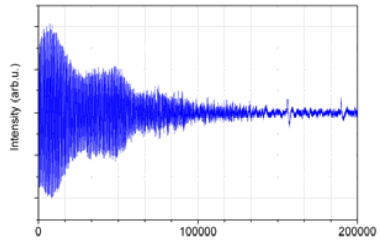
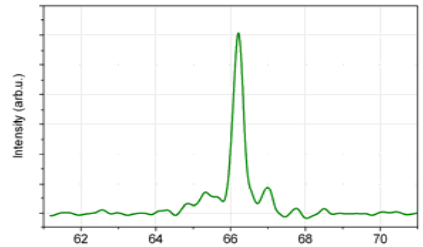
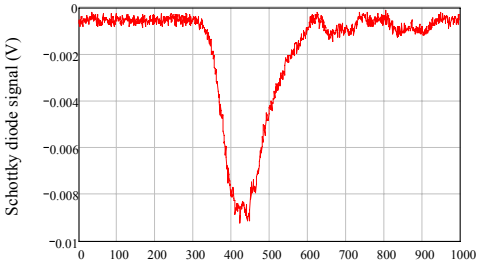
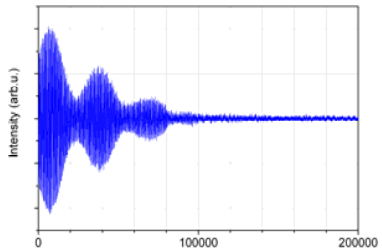
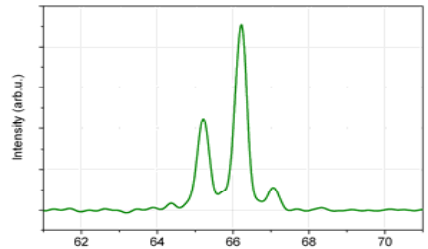
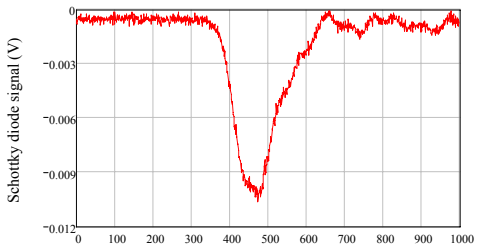
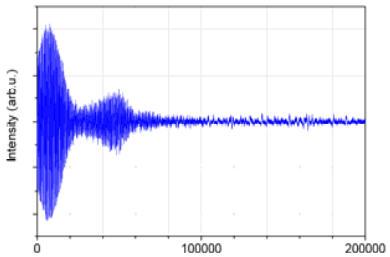
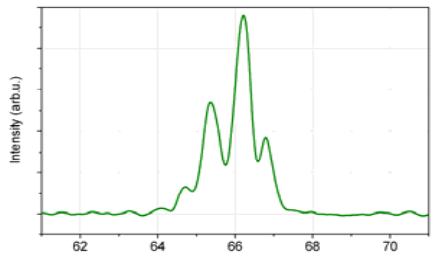
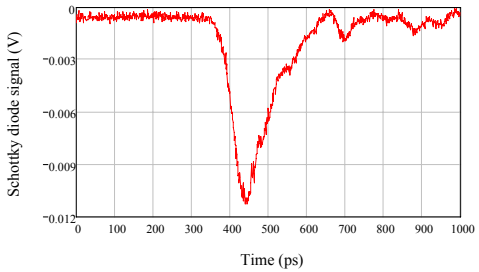
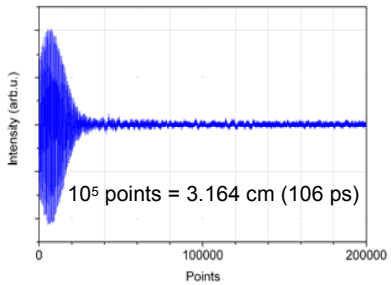
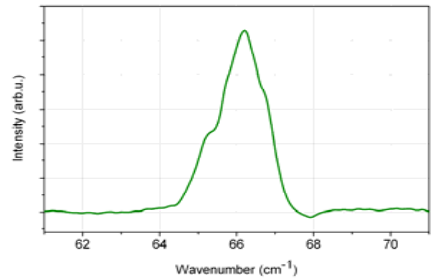
f = 5.6 MHz

Power and spectral width versus detuning of electron beam frequency





Experiment 2007

Pulse:	Interferogram:	Spectrum:	Detuning:
			4 Δf
			3 Δf
			2 Δf
			1 Δf = - 5.54·10^{-6}f
			0

Schottky diode signal (V)

Time (ps)

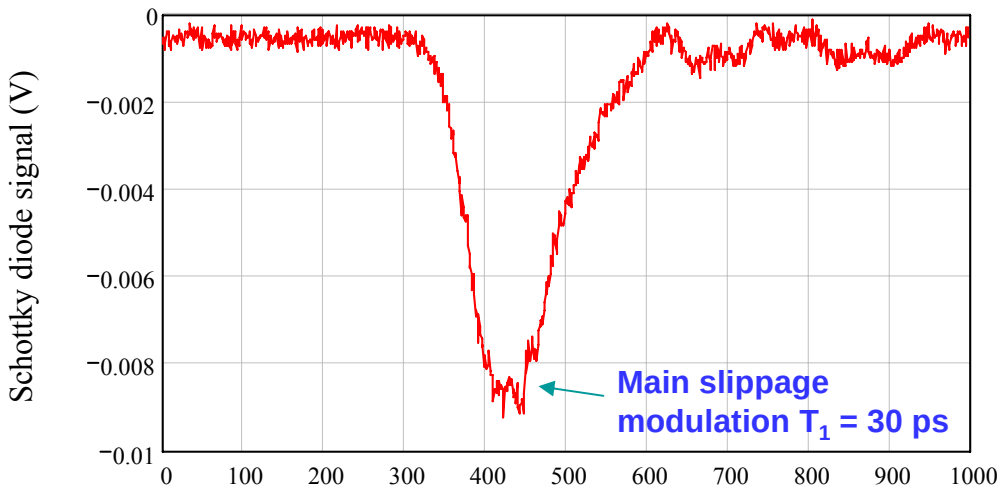
Intensity (arb.u.)

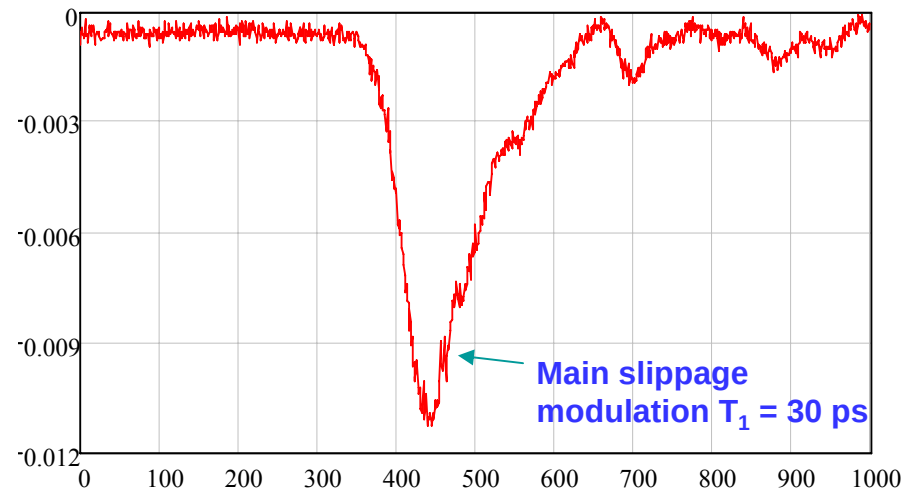
10^5 points = 3.164 cm (106 ps)

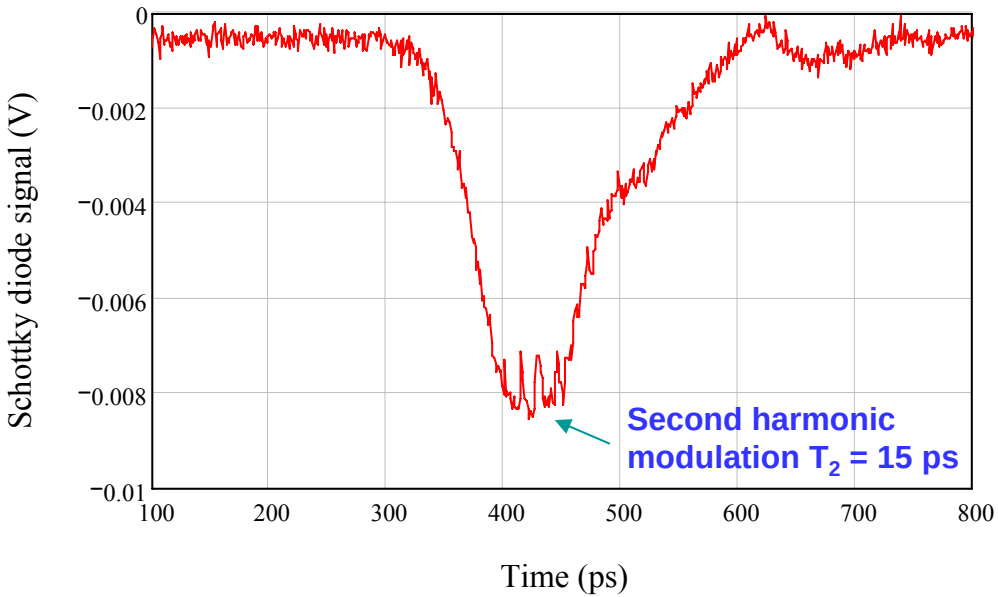
Points

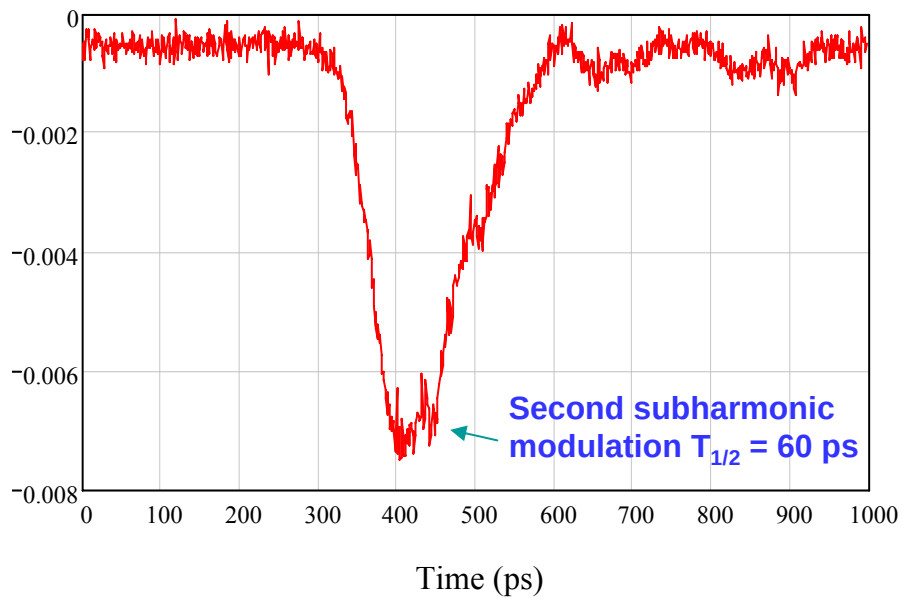
Wavenumber (cm^{-1})

Modulation harmonics in the light pulses



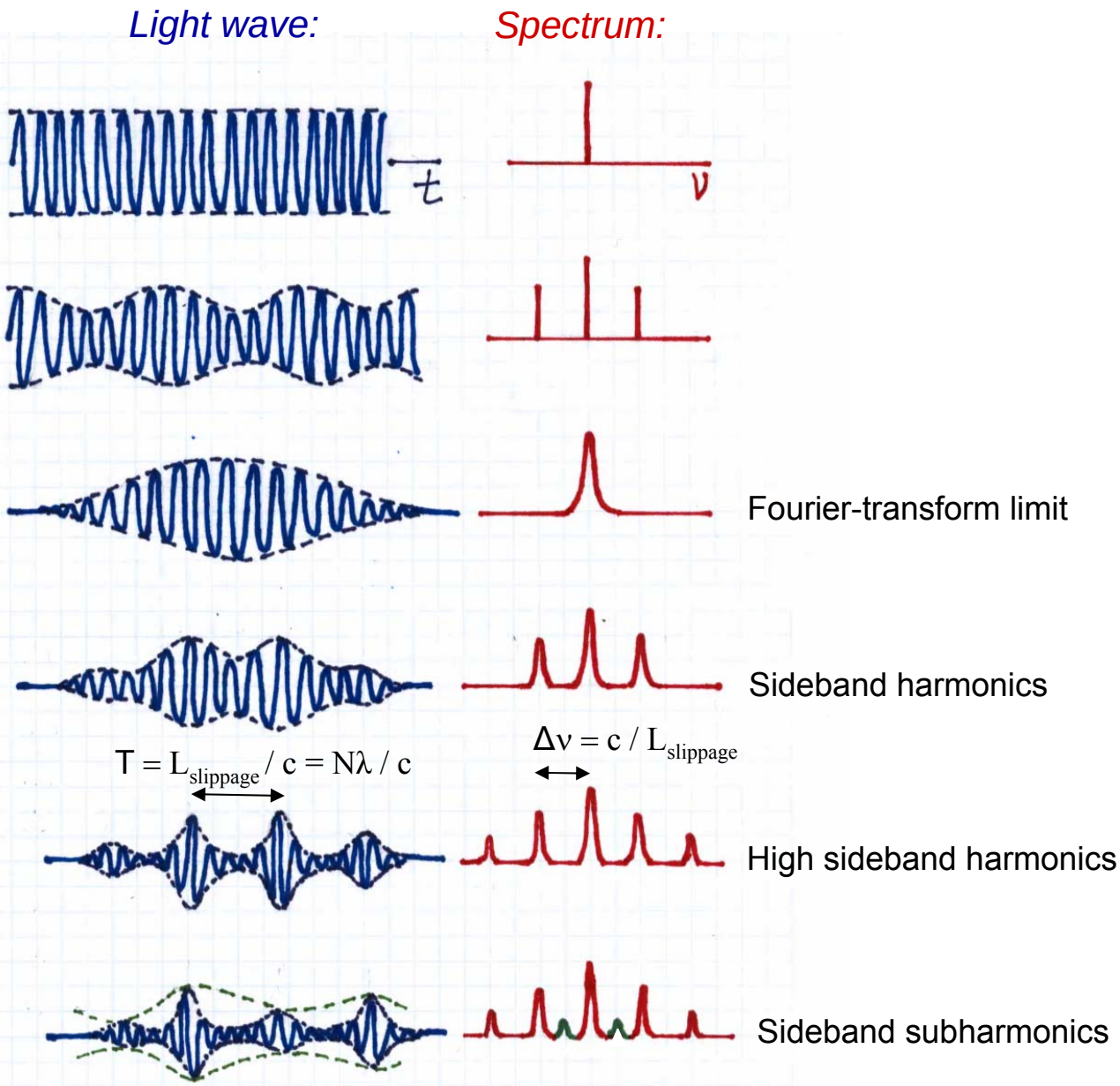




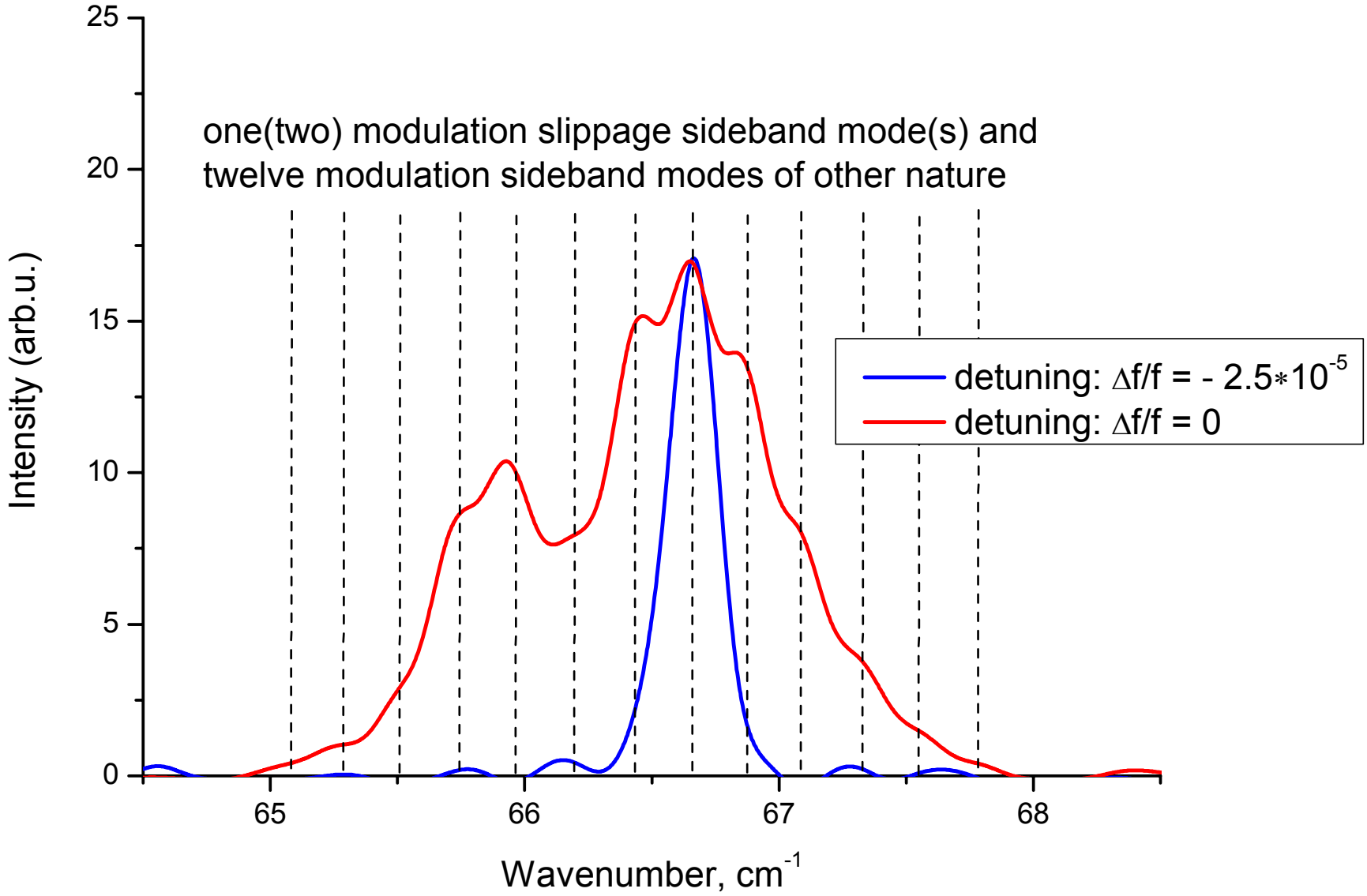


$$T_1 = L_{slippage} / c = N\lambda/c \approx 30 \text{ ps}$$

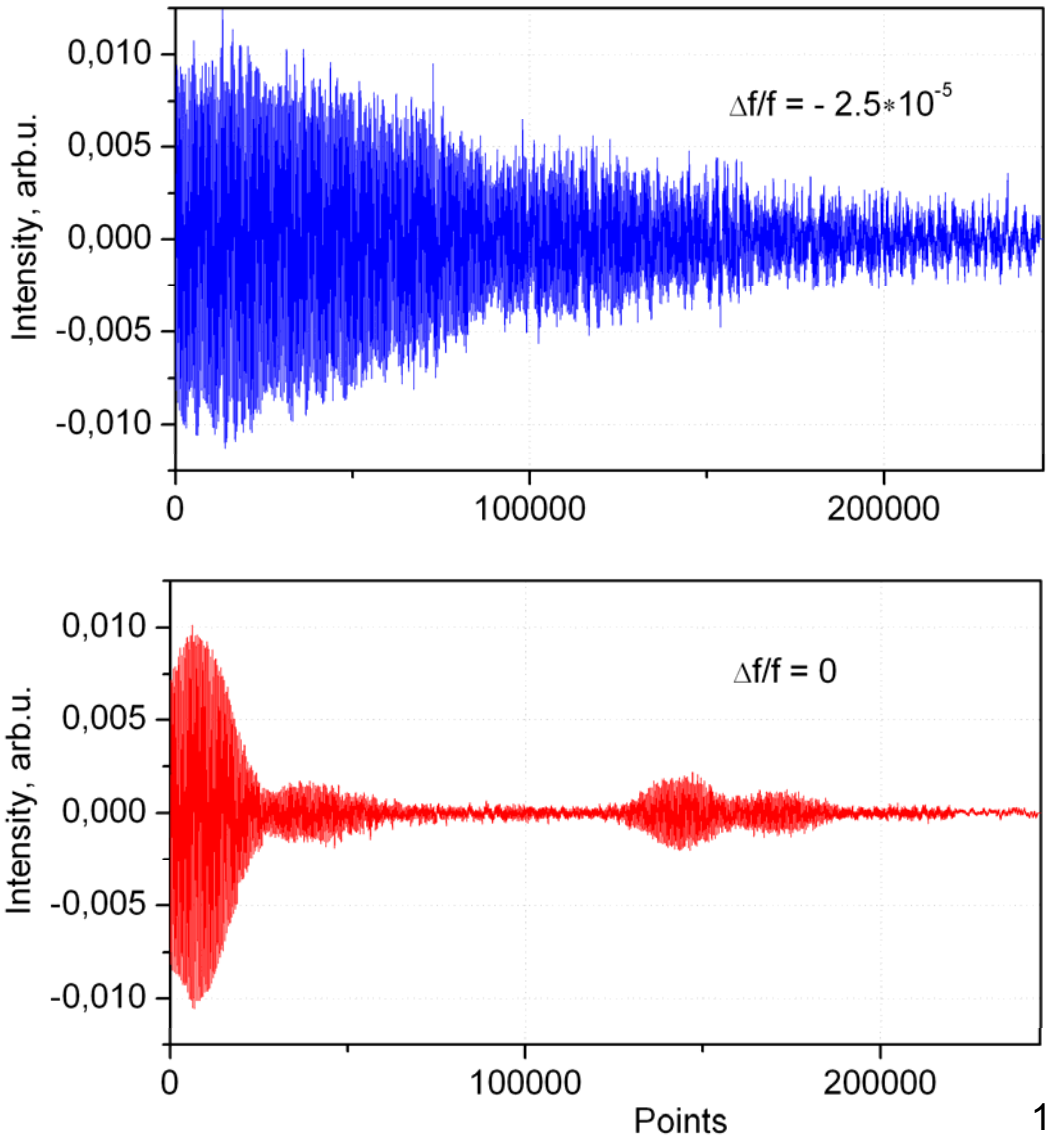
Modulation instability and sideband modes



Two types of sideband modes



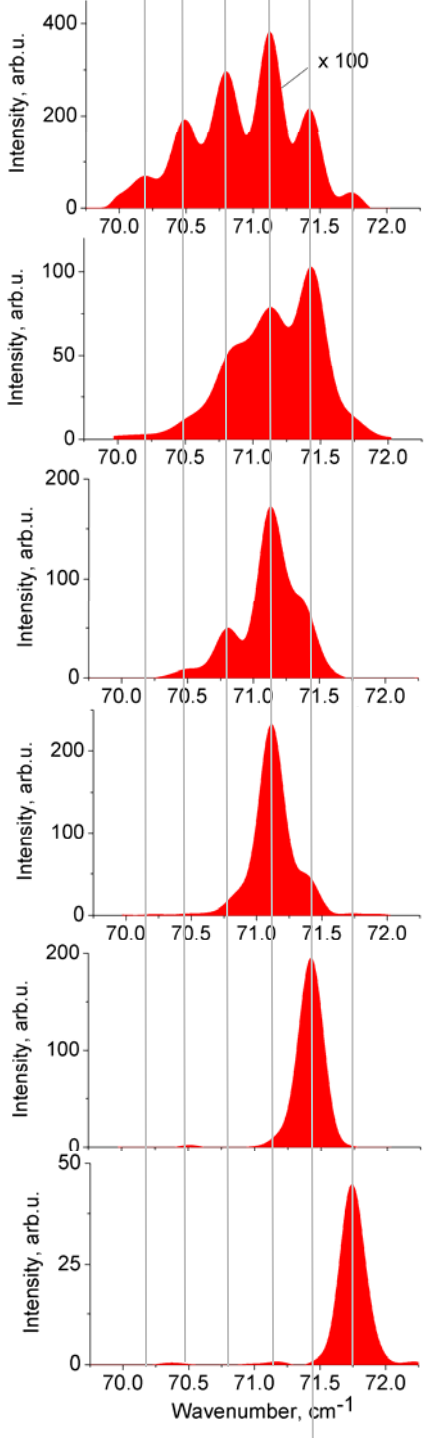
Interferogram of stabilized regime and regime of modulation instability with pulsating coherency



10^5 points = 3.164 cm (106 ps)

Experiment
2006

Spectrums



Detuning Δ f / f

3.3 E -6

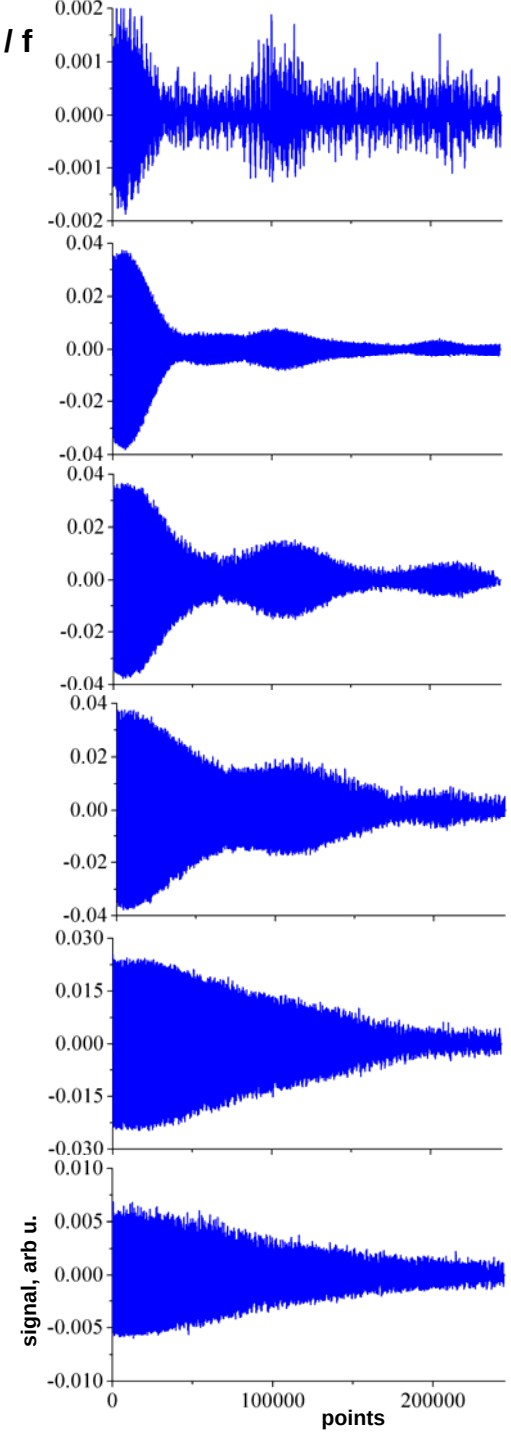
5.5 E -7

-2.2 E -6

-7.8 E -6

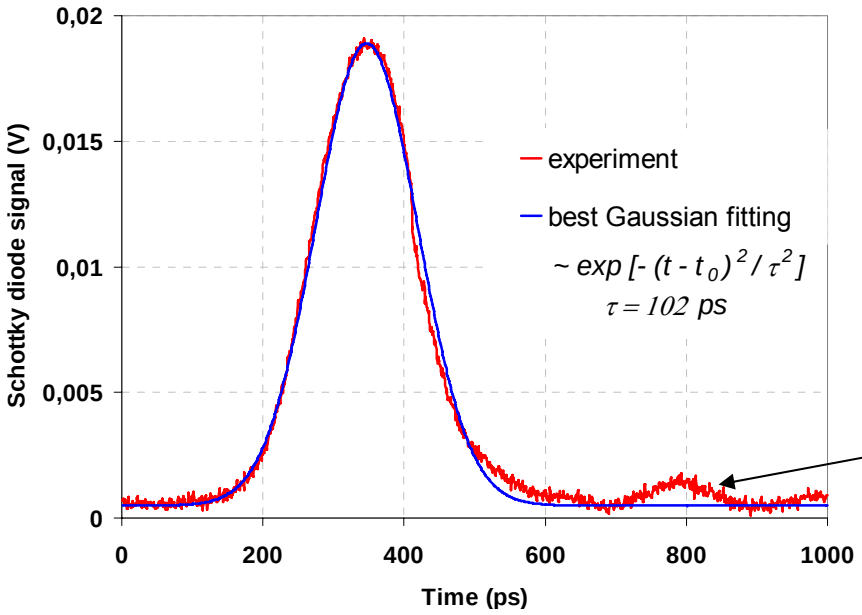
-1.3 E -5

-2.4 E -5



Interferograms

Narrowest spectrum and Fourier transform limit

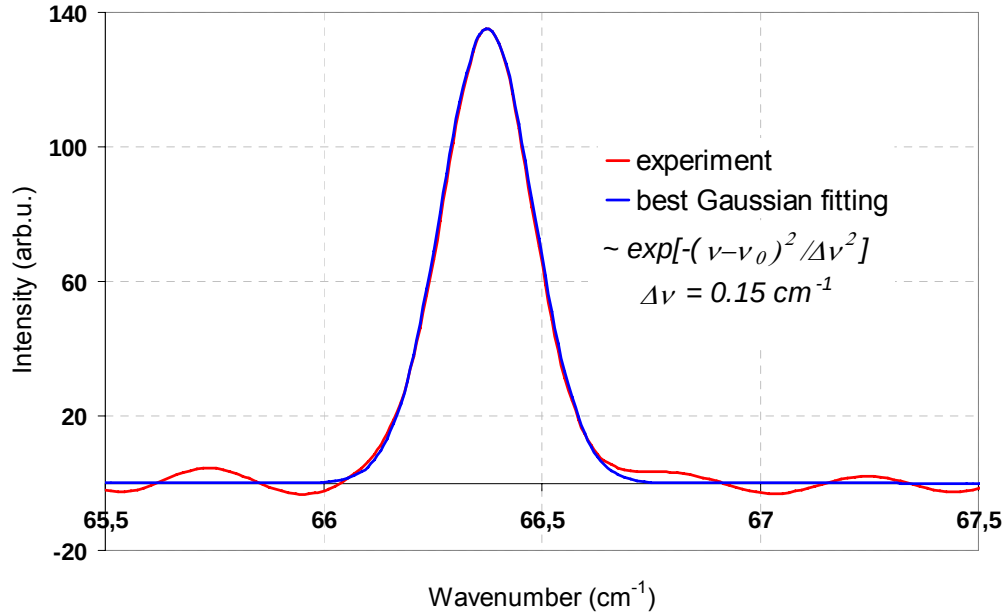


Fourier transform limit (100 % coherency):

$$2\pi\Delta\nu[s^{-1}]\tau = 1$$

$$\Delta\nu\ [cm^{-1}] = (2\pi\tau\ c)^{-1} = 0.052\ cm^{-1}$$

Artifact (reflected parasitic signal)



$$\Delta\nu_{real} = (\ \Delta\nu^2 - 0.072^2)^{1/2} = 0.13\ cm^{-1}$$

Instrumental function of Fourier spectrometer

Spectral range of Novosibirsk terahertz FEL

- First harmonic: 120 – 235 μm
- Second harmonic: 60 – 118 μm
- Third harmonic: 40 – 78 μm
- Total range: 40 – 235 μm

Harmonic powers

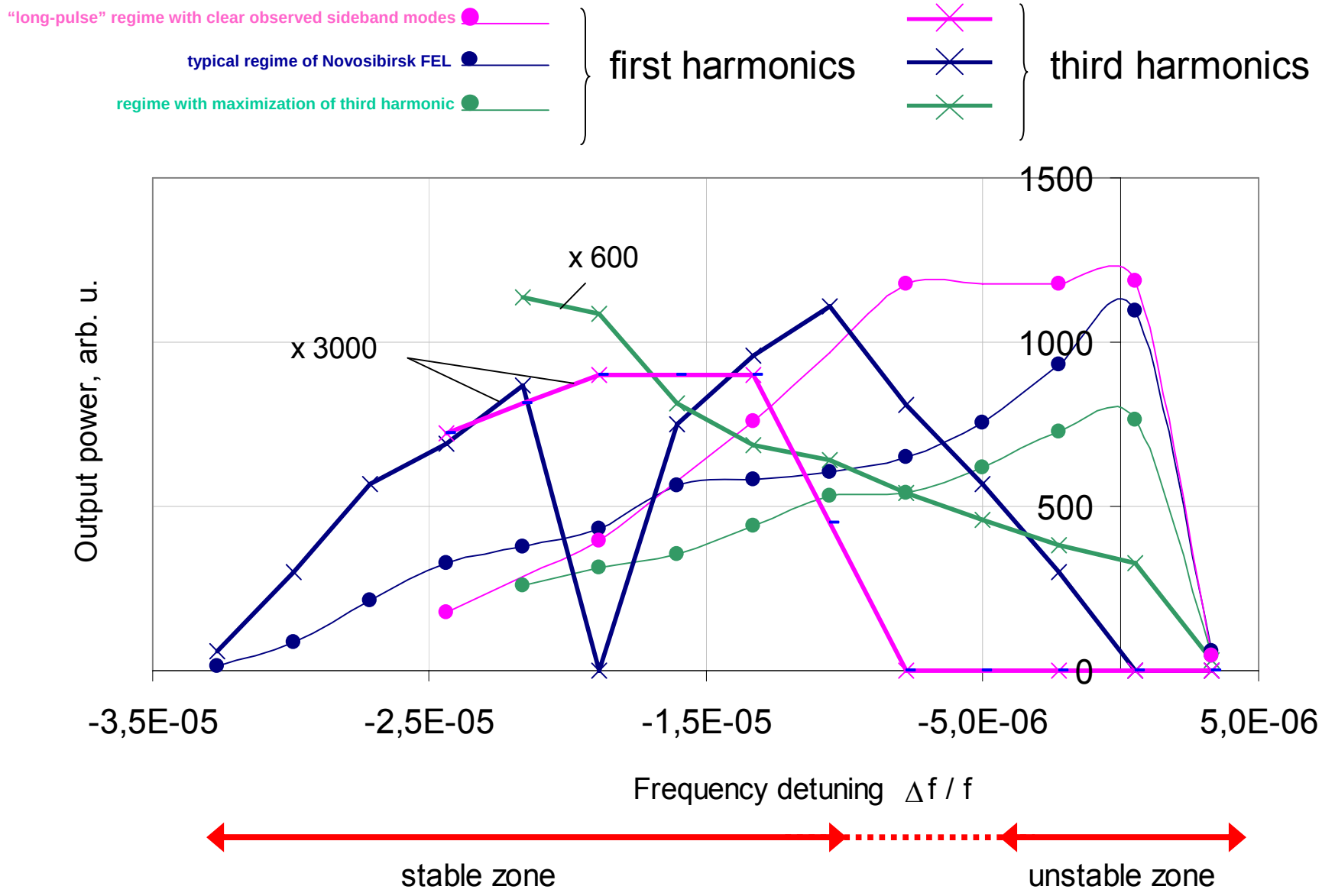
- First harmonic: 370 (430) W 100 %
- Second harmonic: 370·0.5·0.015 = 2.8 W 1.5 %
- Third harmonic: 370·0.5·0.006 = 1.1 W 0.6 %

Only few gas laser lines in the range have power ~ 1 W.

But overlapping of the spectral range by gas laser lines is 1% only!

Experiment
2006

Detuning curves of Novosibirsk FEL



Conclusion

- Spectral and temporal properties of NovoFEL radiation were measured independently.
- In stabilized regime with high coherency spectral width is close to Fourier-transform limit.
- Method of the stabilization is negative electron frequency detuning.
- In unstable regime spectral width can be larger in 3-7 times.
- Main reason of the spectral broadening is slippage and modulating sideband instability. Two types of the modulation instability were observed.
- Three mode regimes were found:
  - single-mode regime with high coherency
  - multi-mode regime with high coherency
  - mode-mixing (quasi single-mode) regime with low coherency.
- Harmonics of NovoFEL are radiated effectively only in stabilized regime.