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Development, Science and Emerging Applications

Limits of the temporal contrast for CPA lasers with beams of high aperture

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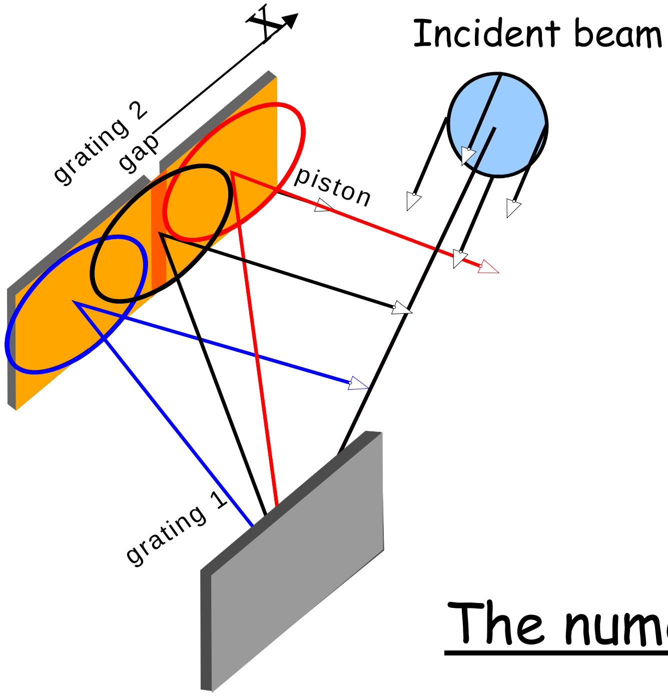
Computer model



- Spectral clipping in compressor, stretcher and influence of the beam aperture (phase and amplitude)
- Spectral filtering with mirrors
- Clipping with tiled diffraction gratings and misalignment
- Influence of B-integral

The numerical model considers:

- propagation of a stretched pulse through medium and a diffraction grating based compressor
- the finite size of the incident beam
- effects of spectral clipping appearing in compressor and amplifiers
- slight misalignment of the compressor gratings (piston, tilt)
- self-phase modulation of the chirped pulse

In some cases MIRÓ – code was used

Pulse steepening, contrast at the pulse front

Intensity contrast:

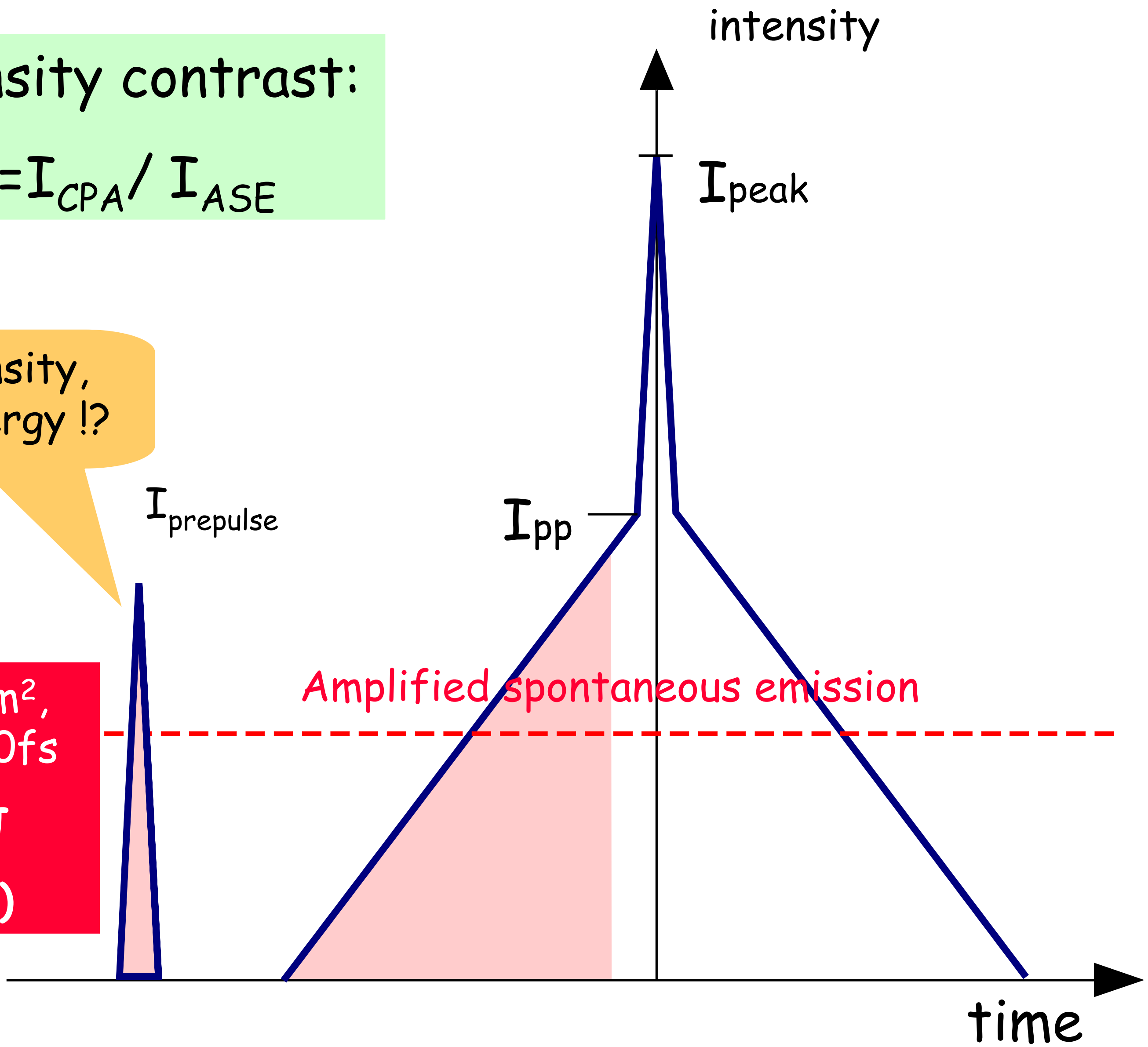
$K_I = I_{CPA} / I_{ASE}$

High intensity, but low energy !?

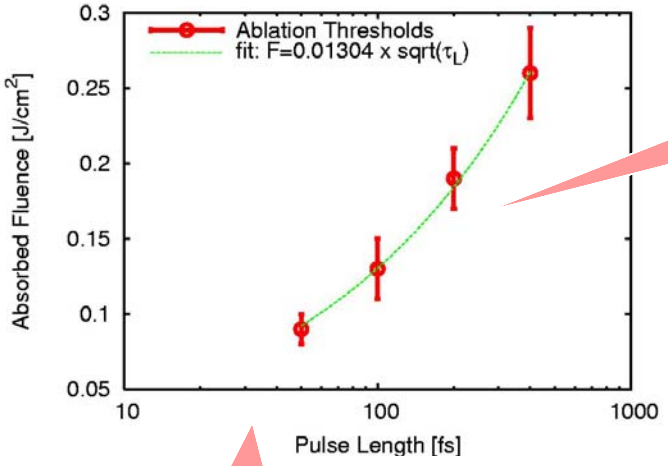
At $I_{peak}=10^{20} W/cm^2$, $C=10^{10}$, E= 1J, t=10fs

$E_{prepulse}$=0.1nJ

($J=10^{-4} J/cm^2$)

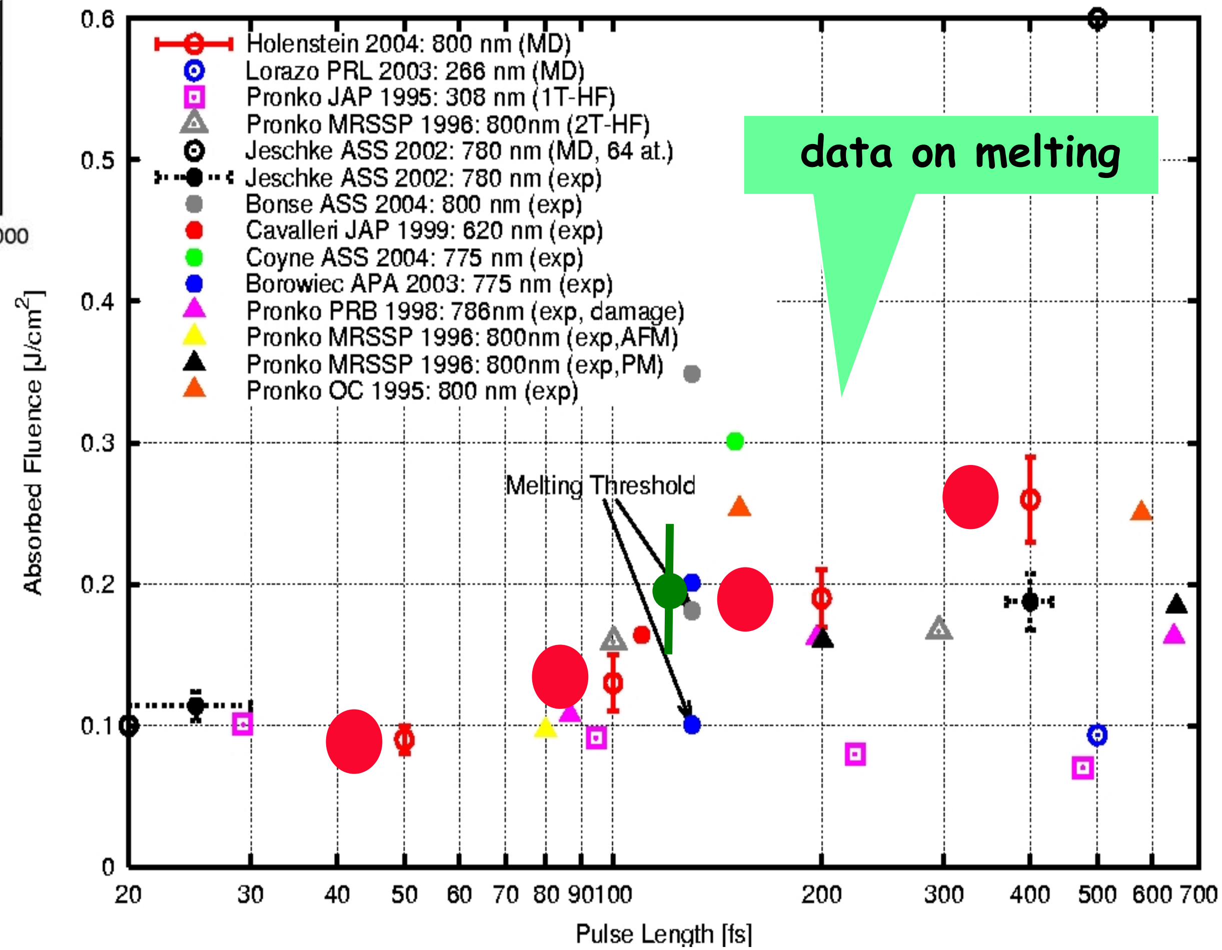


Ablation and Melting Thresholds



Two Temperature Model of Corkum et al.,PRL 25, 2886 (1988)

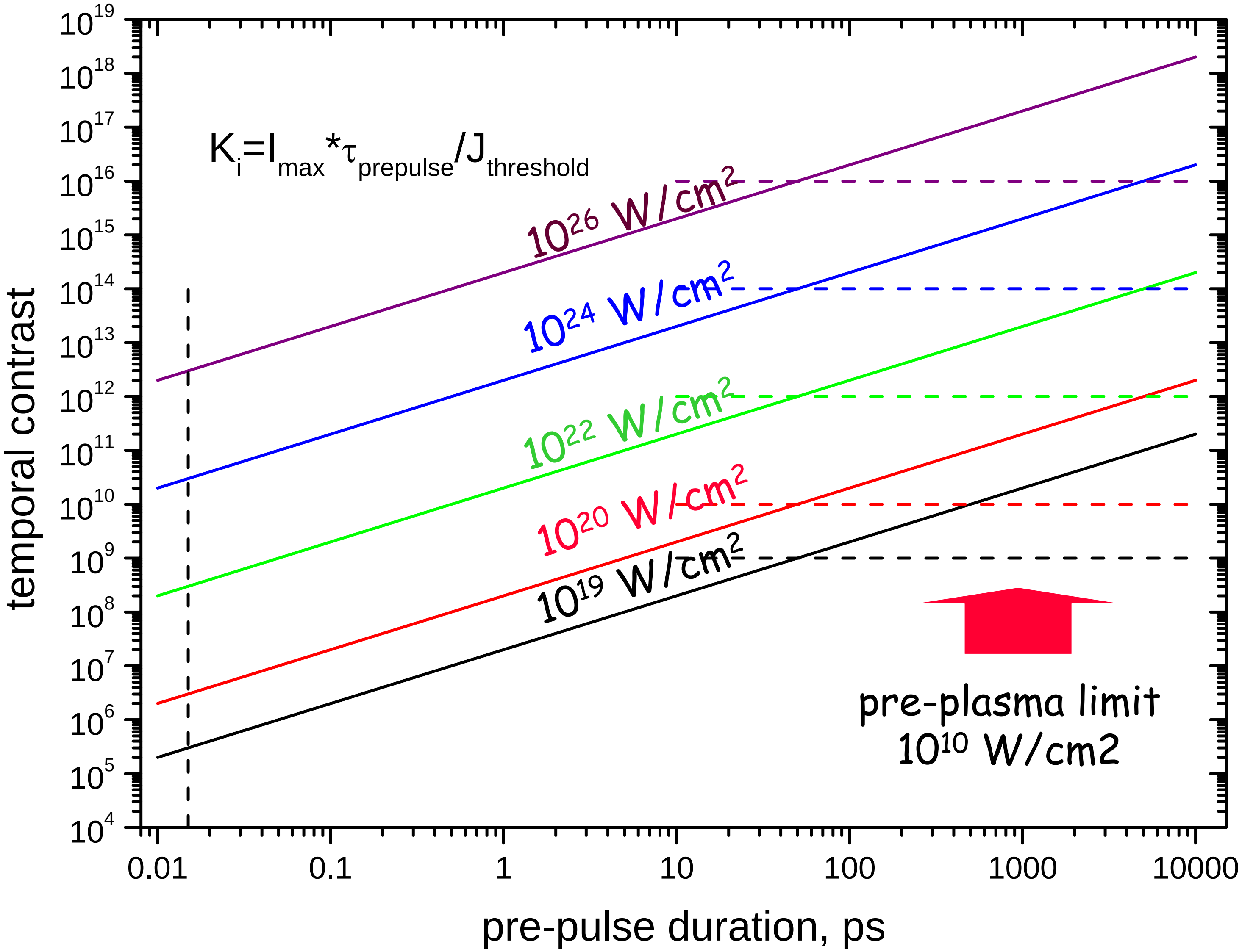
Square root scaling on laser pulse duration assuming two photon absorption For duration greater than 100 fs avalanche ionisation will be important, this will reduce the predicted threshold.



data on melting

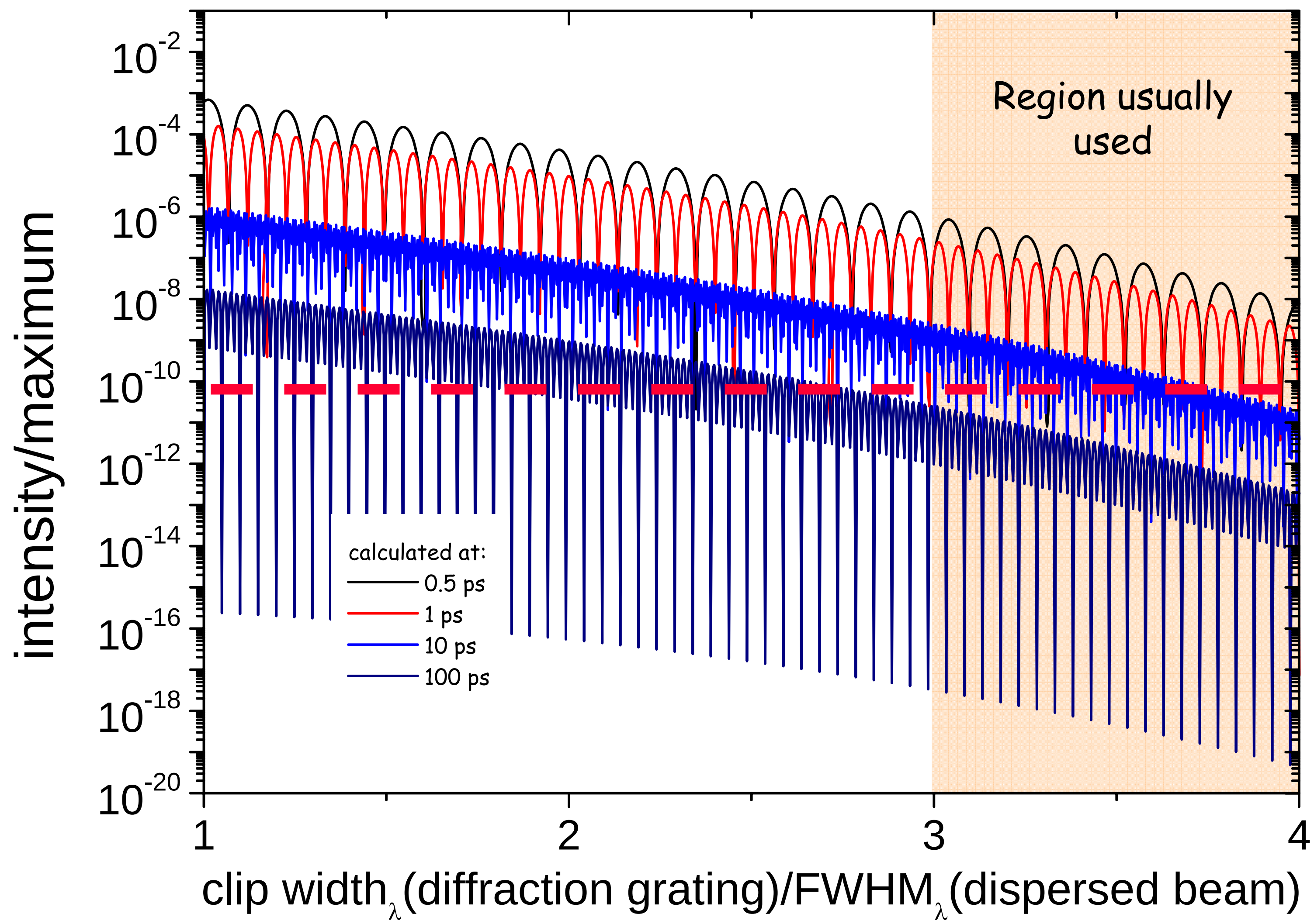
Dependence of temporal contrast on pre-pulse duration

assuming energy density threshold= 0.5/cm²



Hard clipping of spectrum, the stretcher

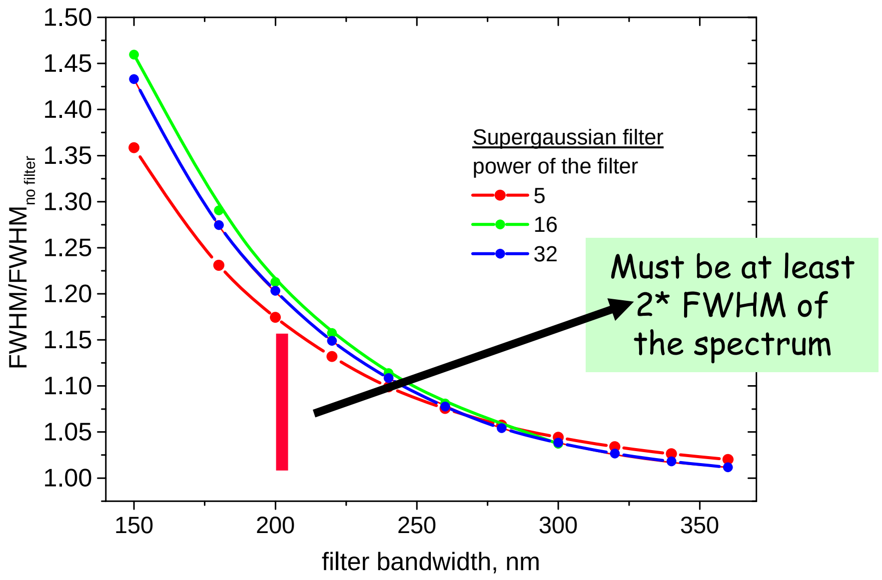
narrow beam case is typical for the stretcher



Pulse FWHM on bandwidth of the filter

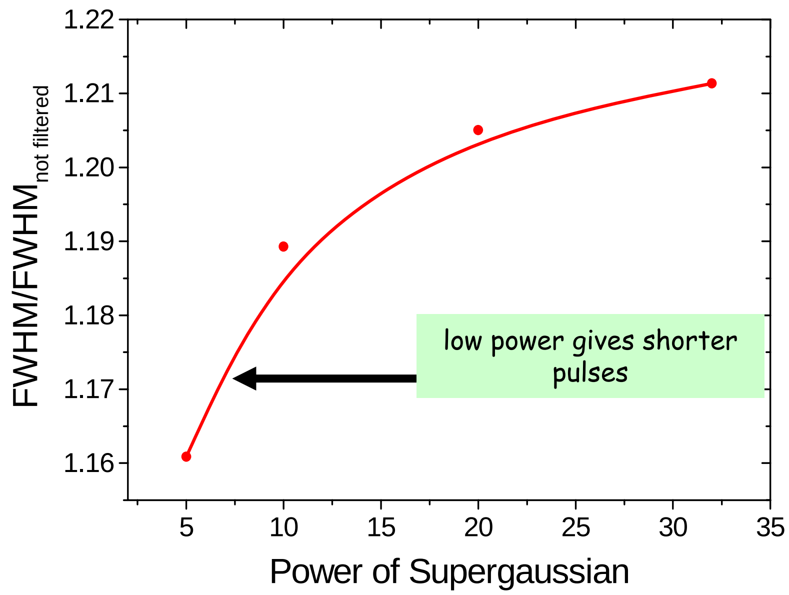
Supergaussian filter

Initial pulse spectrum: FWHM=100 nm



Supergaussian filter Δλ = 200nm,

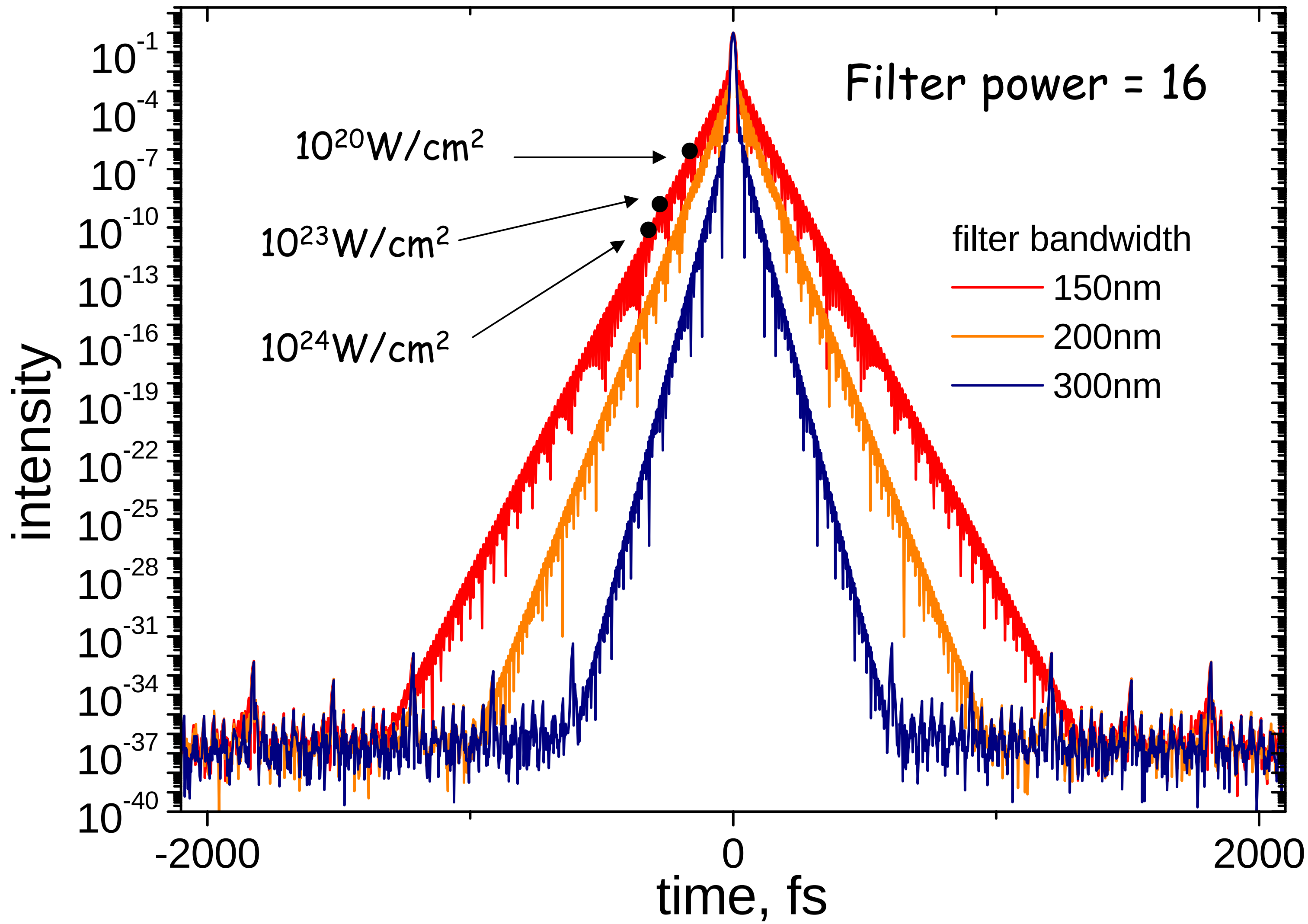
initial pulse bandwidth Δλ = 100 nm



Influence of dielectric mirros, bandwidth

Supergaussian filter

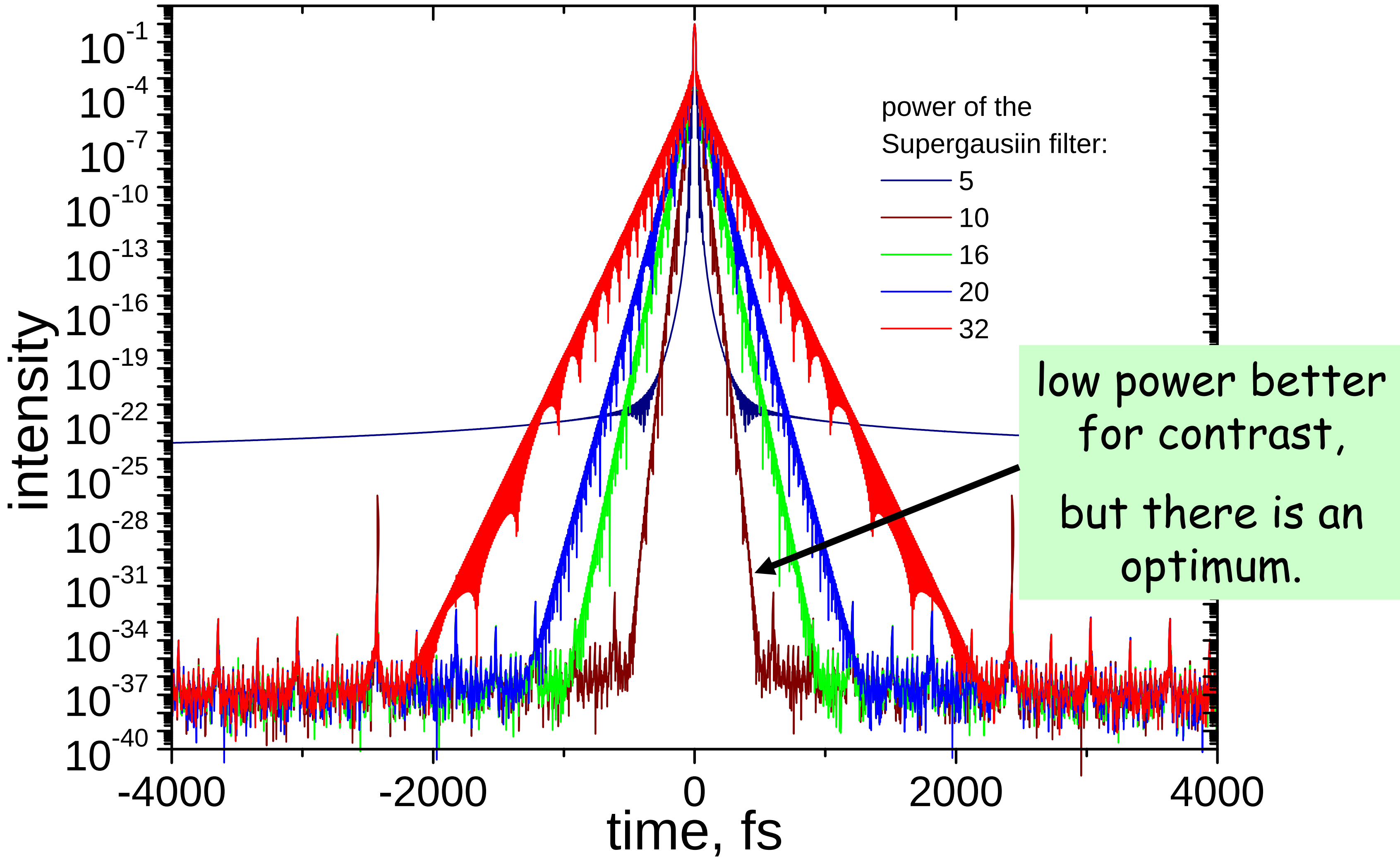
Pulse bandwidth $\Delta\lambda$ = 100 nm



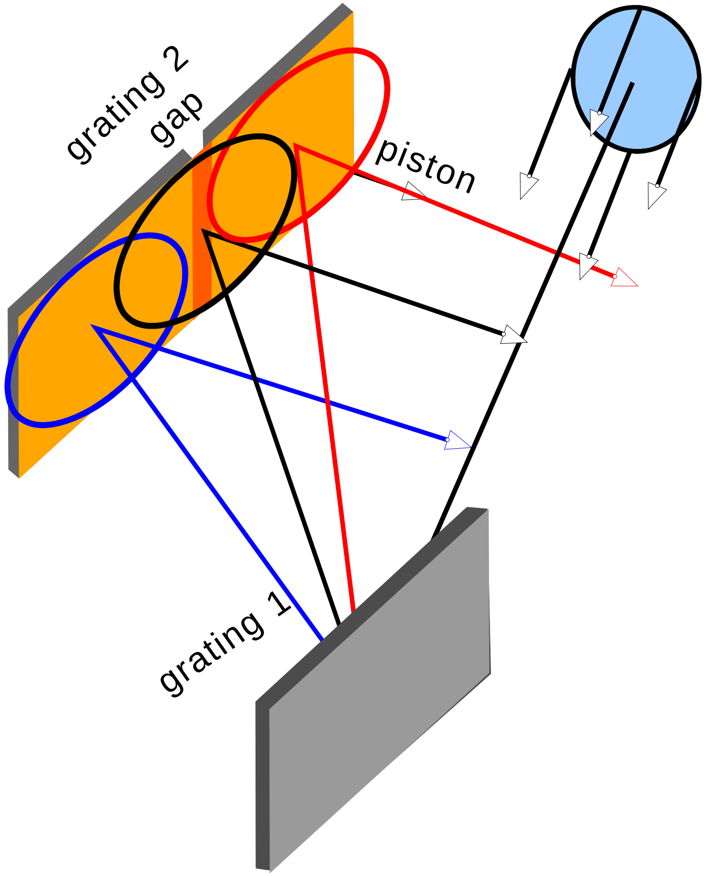
Influence of dielectric mirros, SG power

Supergaussian filter $\Delta\lambda$ = 200 nm

Pulse bandwidth $\Delta\lambda$ = 100 nm



Clipping of spectrum in the compressor



Incident beam

Typical parameters:

gr. constant = 1480 l/mm

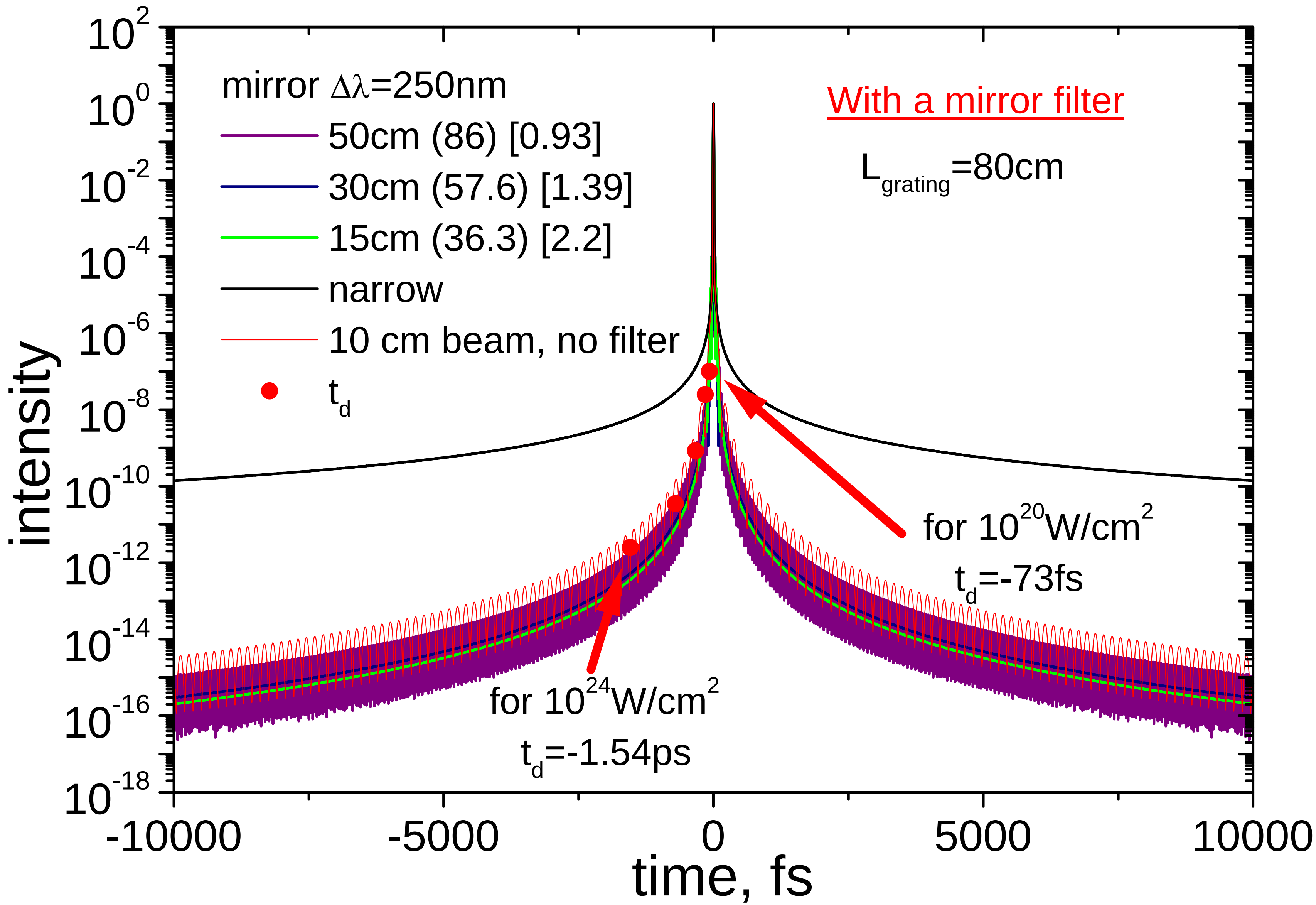
$L_{grating\ 2}$ = { 40cm – 2m }

L_{compr}= 82 cm

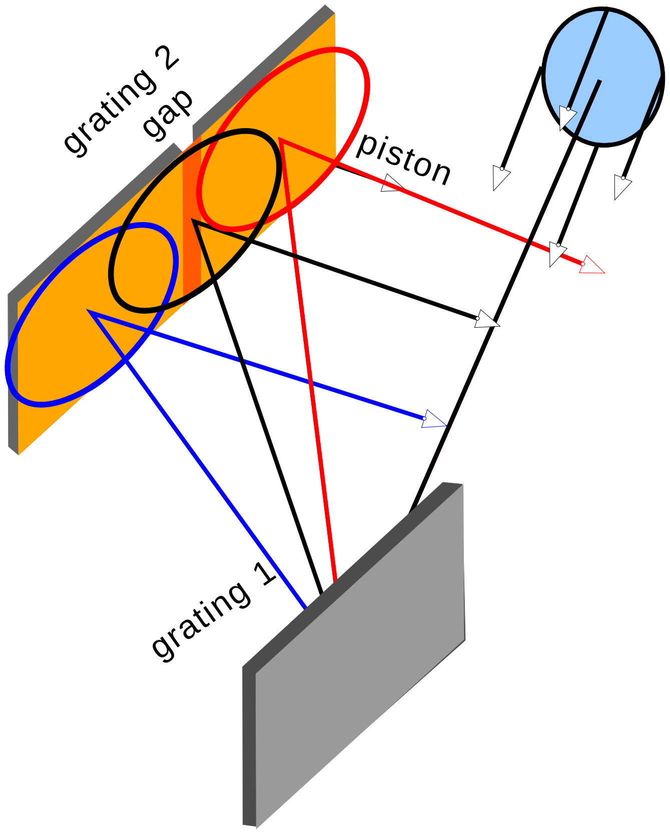
Pulse bandwidth $\Delta\lambda$ = 100 nm

Beam diameter = { 0 – 90cm }

Influence of the beam aperture and filtering



Clipping in compressor

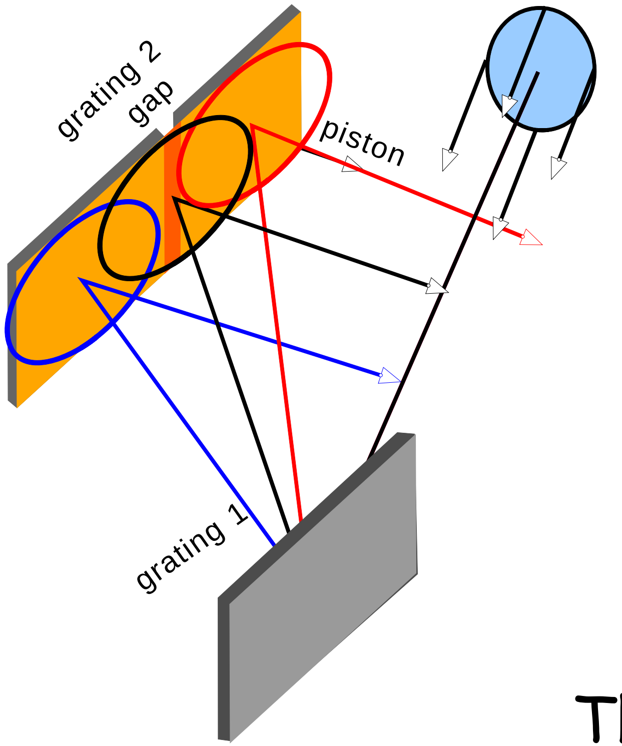


The beam diameter must be big enough (projection on the second diffraction grating bigger than the with of the dispersed spectrum of a narrow beam)

The diffraction grating must be ~1.5 times bigger than the FWHM of the dispersed beam on the second diffraction grating ($L_{grating}$>1.5*$FWHM_w$)

Tiled diffraction gratings

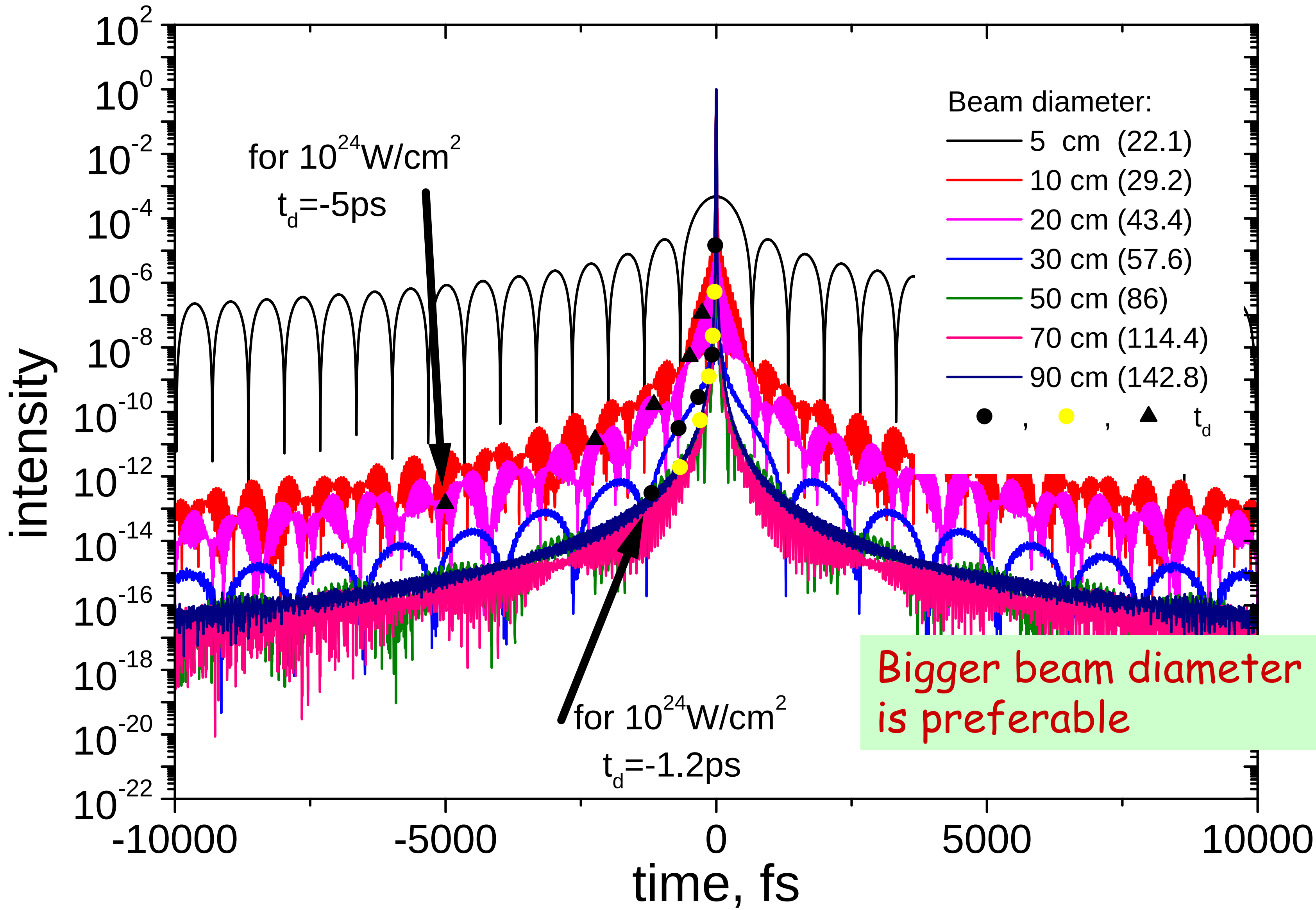
Incident beam



Influence of a gap

The beam diameter of 0-60 cm,
gratings size 160cm
gap widths 0.5 cm

Influence of gaps, beam diameter



Bigger beam diameter is preferable

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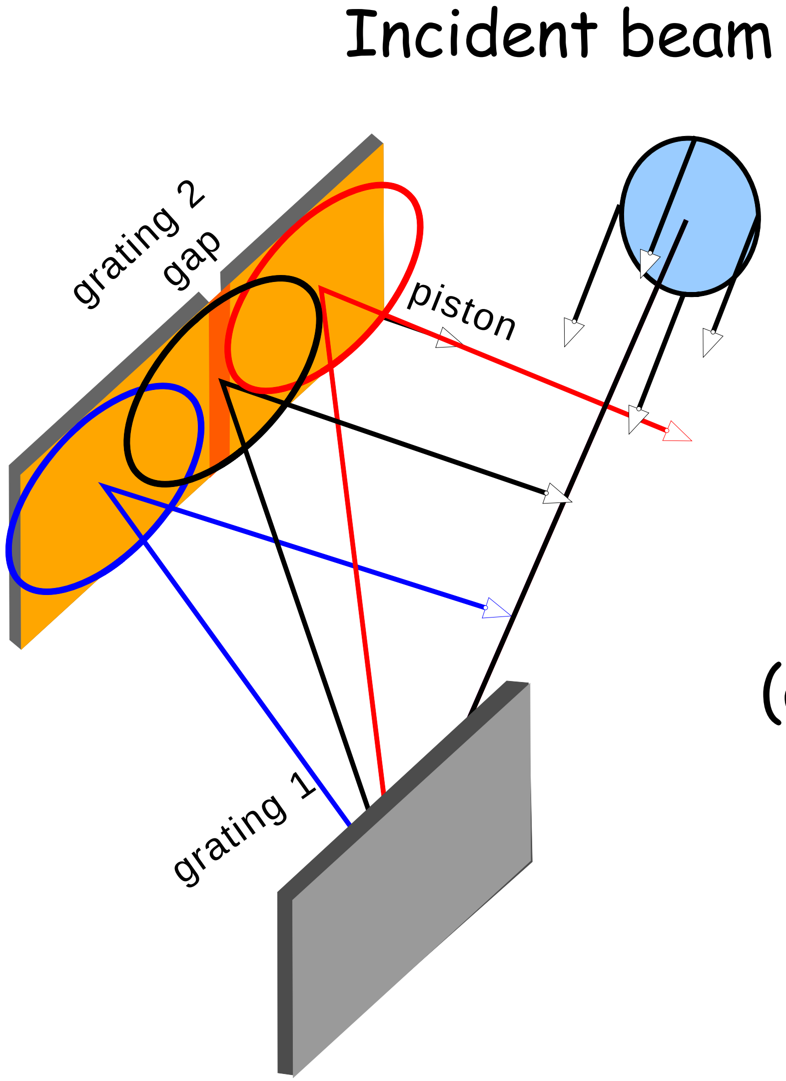
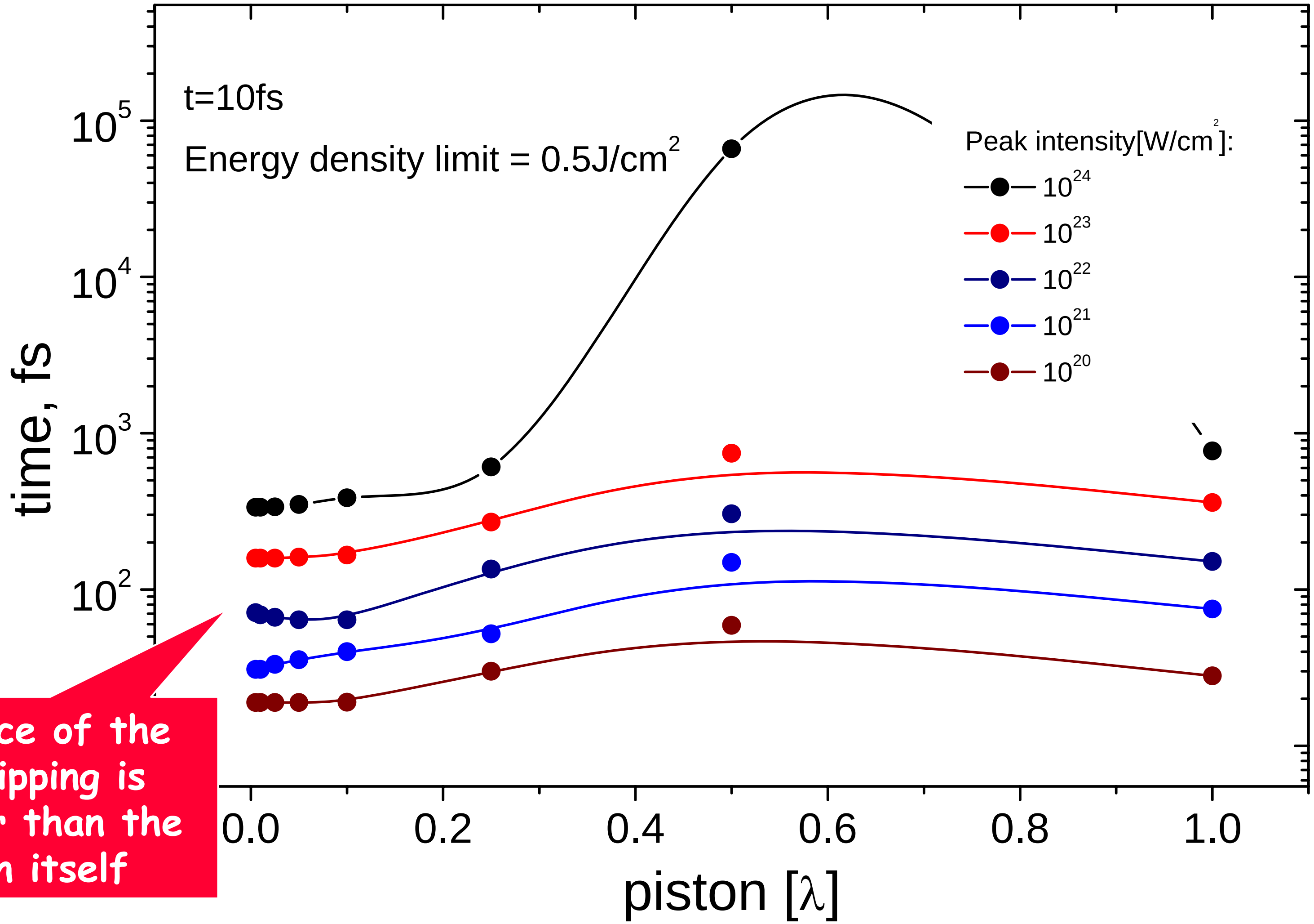


Piston

(a jump of the spectral phase)

Influence of a piston, accumulated pre-pulse

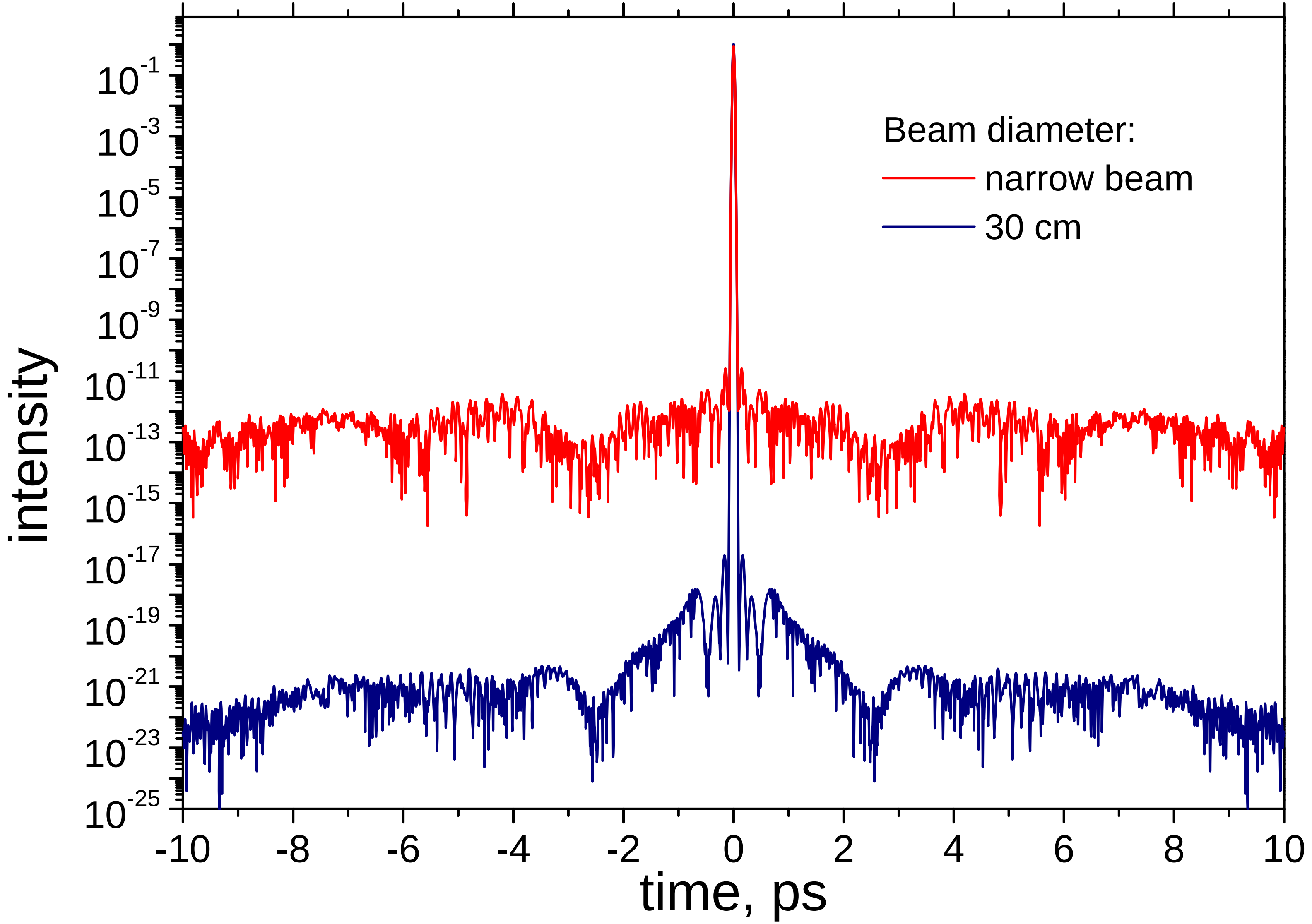
Beam diameter = 50 cm, Δλ = 100 nm



Influence of the gap clipping is stronger than the piston itself

Surface quality of diffraction gratings

noisy surface of the grating with RMS = 0.1 wave



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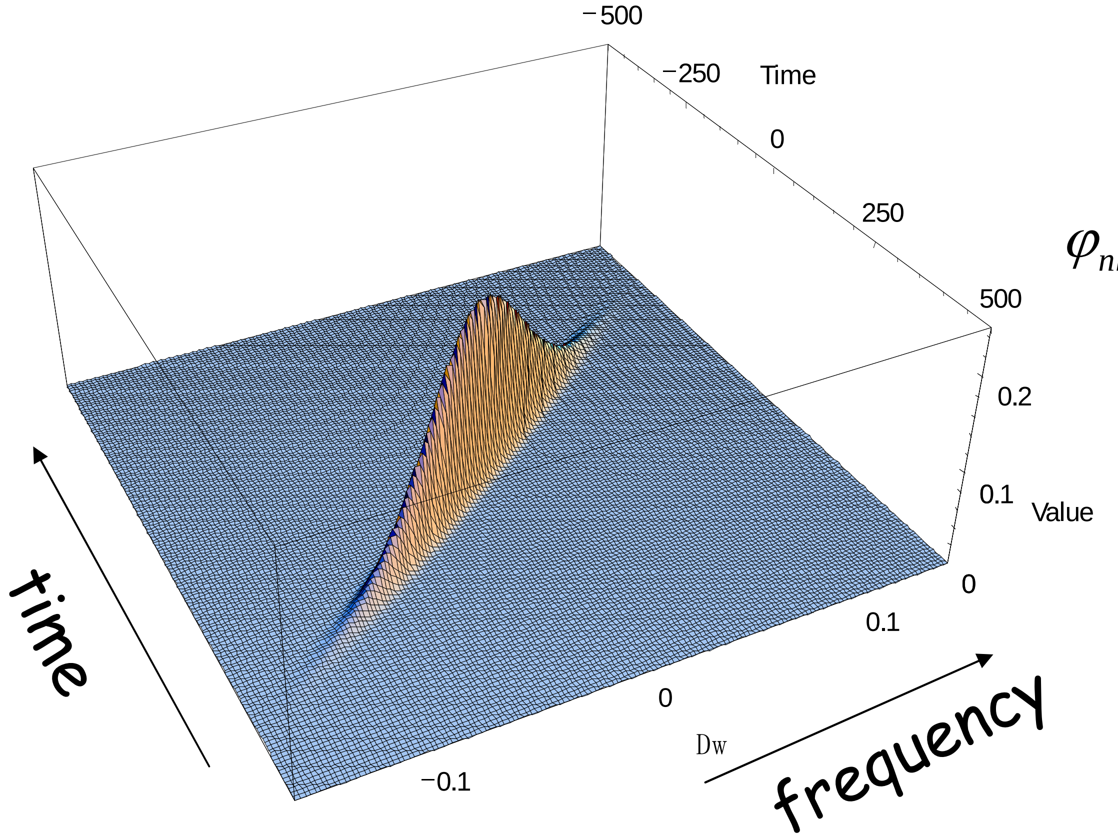
Influence of self-phase modulation



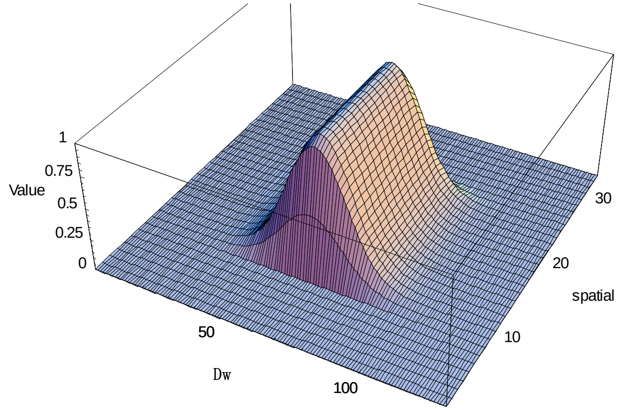
$$\Delta\omega(t) = \frac{2\sqrt{2\log(2)}}{GVD\cdot\sigma_\omega} \approx 2-3\,pm$$

$$\varphi_{nl} = \frac{2\pi}{\lambda}\cdot n_2 I(t) L \approx \frac{2\pi}{\lambda}\cdot n_2 I(\omega) L$$

The time sacle can be substituted by the frequency scale

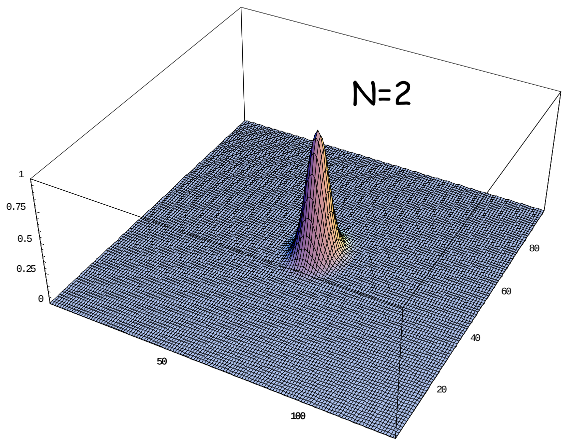
Reduction of peak intensity on the breakup integral

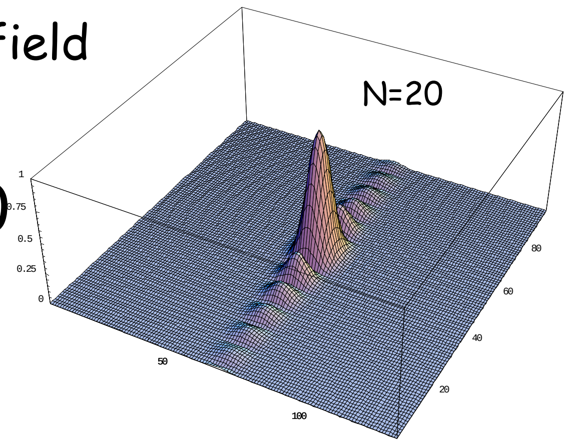
Near field, input



far field

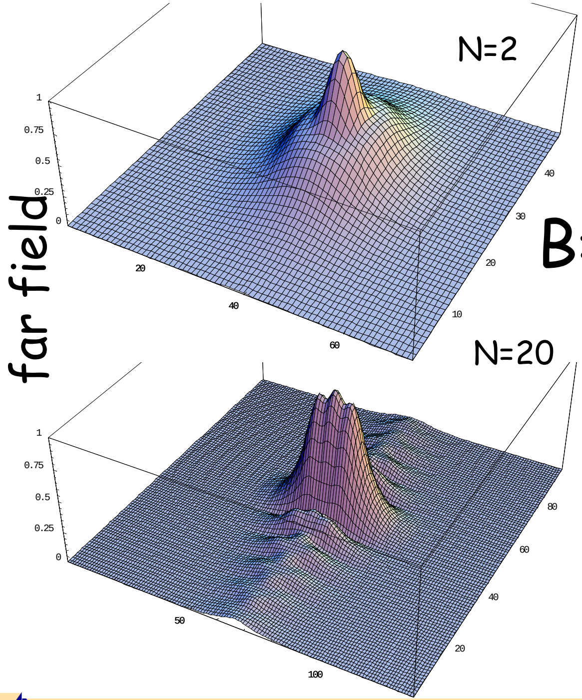
B=0

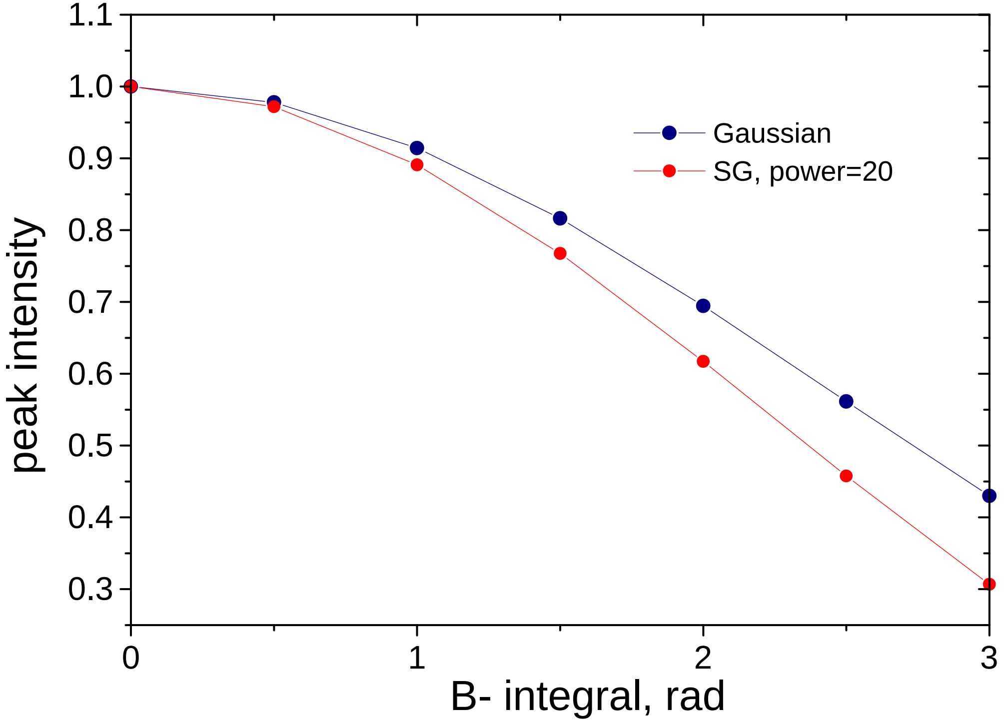




far field

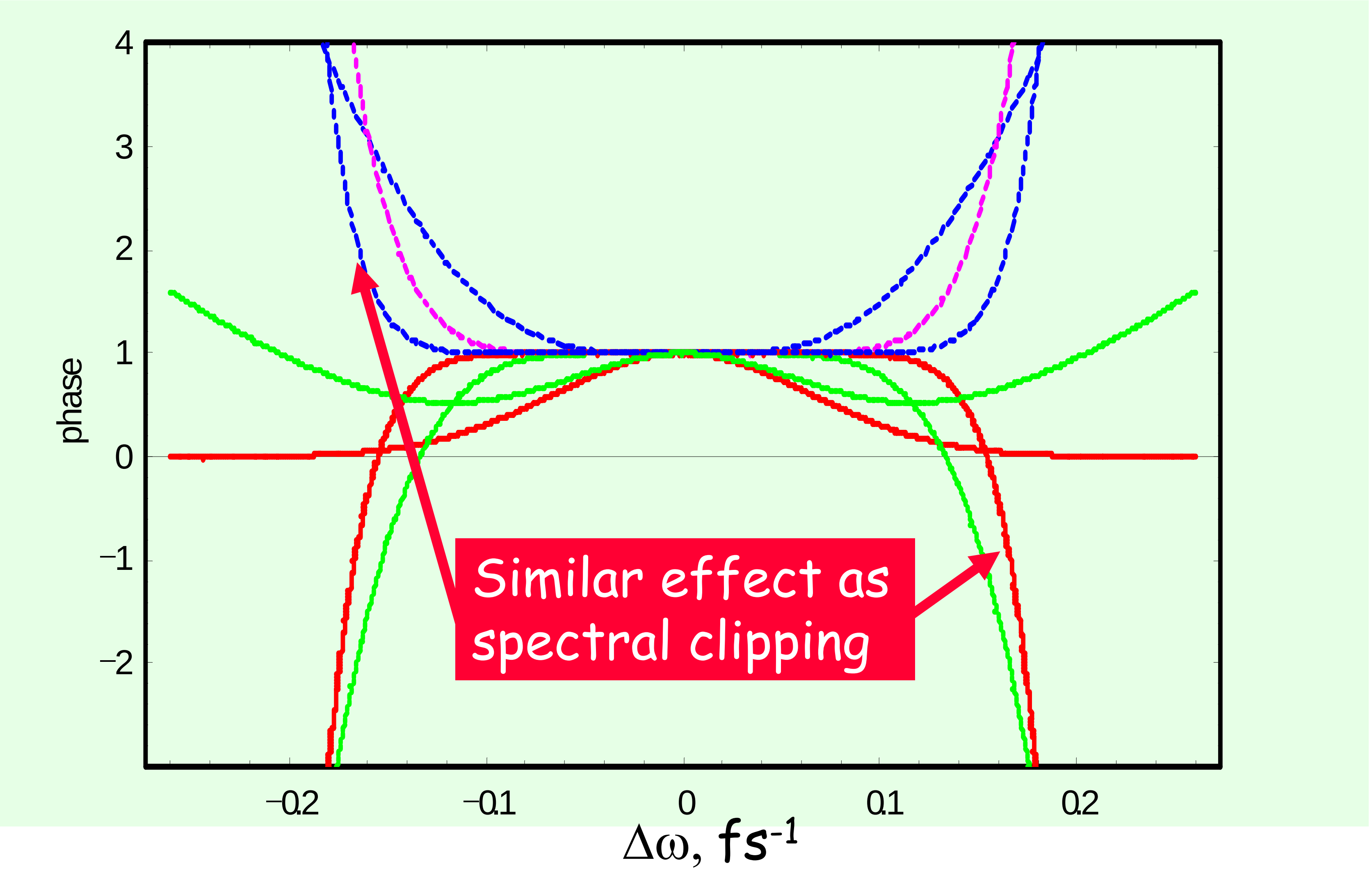
B=3



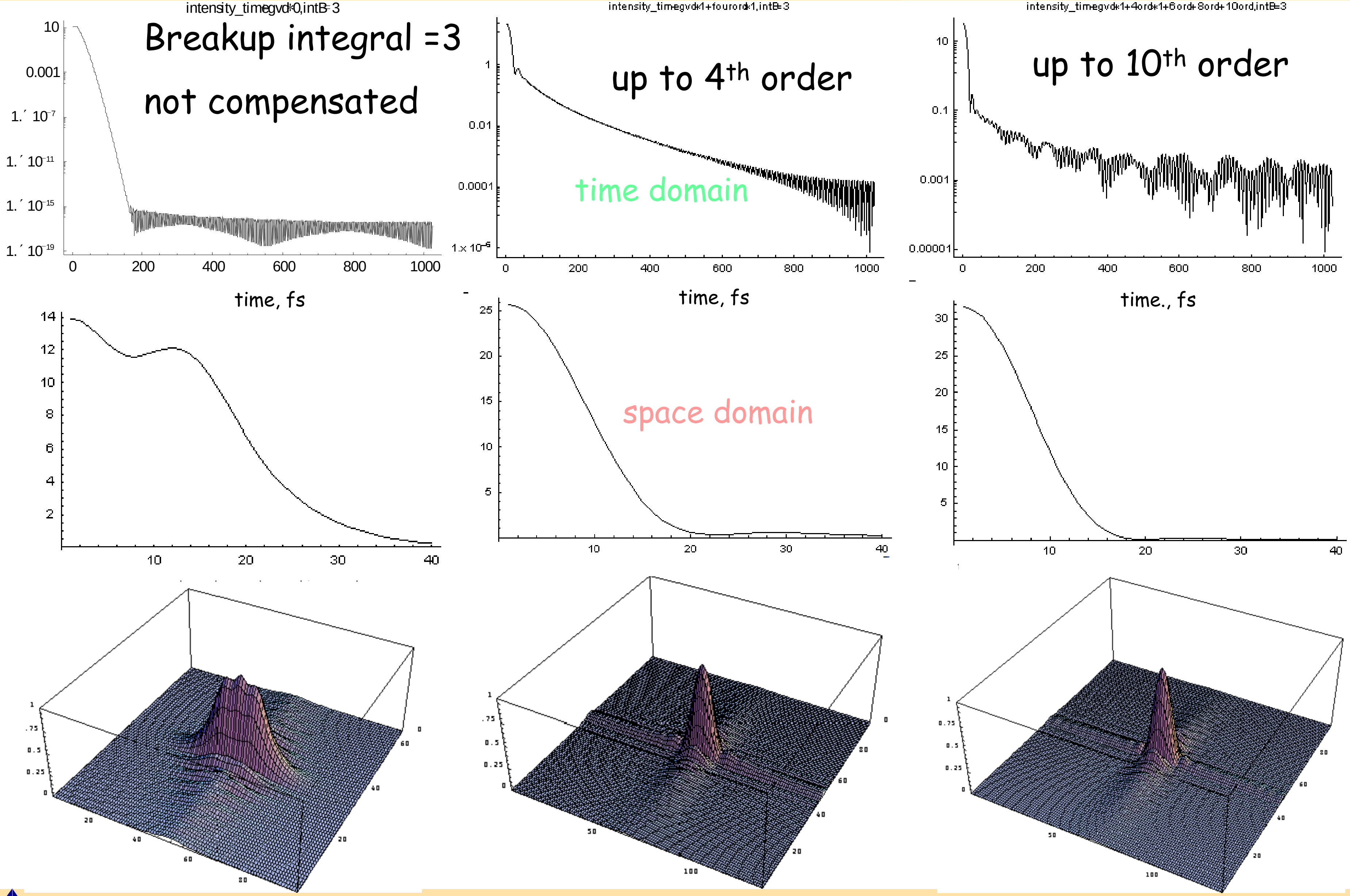


Deformation of spectreal phase with SPM

Residual spectral phase after compensation



Compensation of high orders of dispersion



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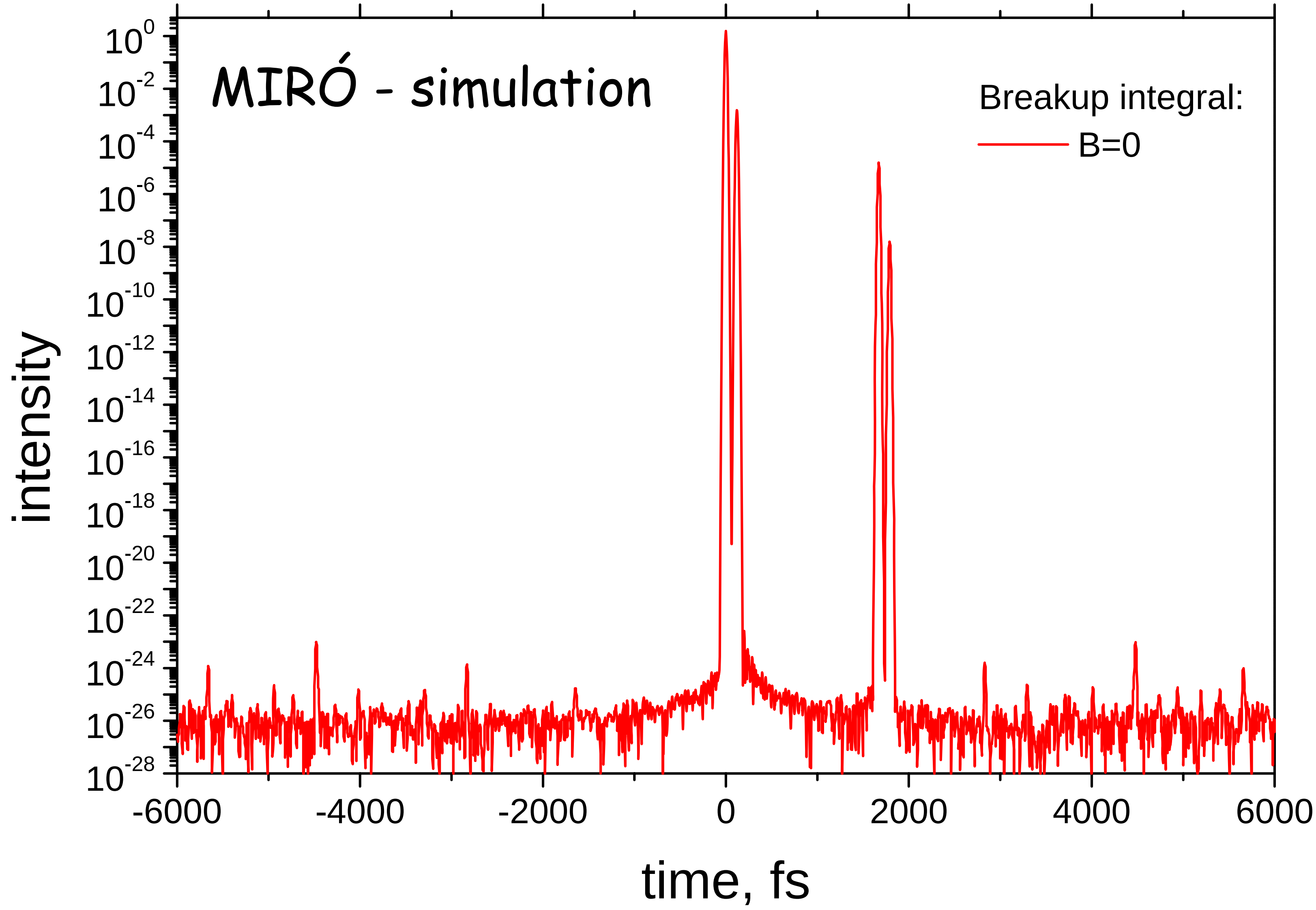
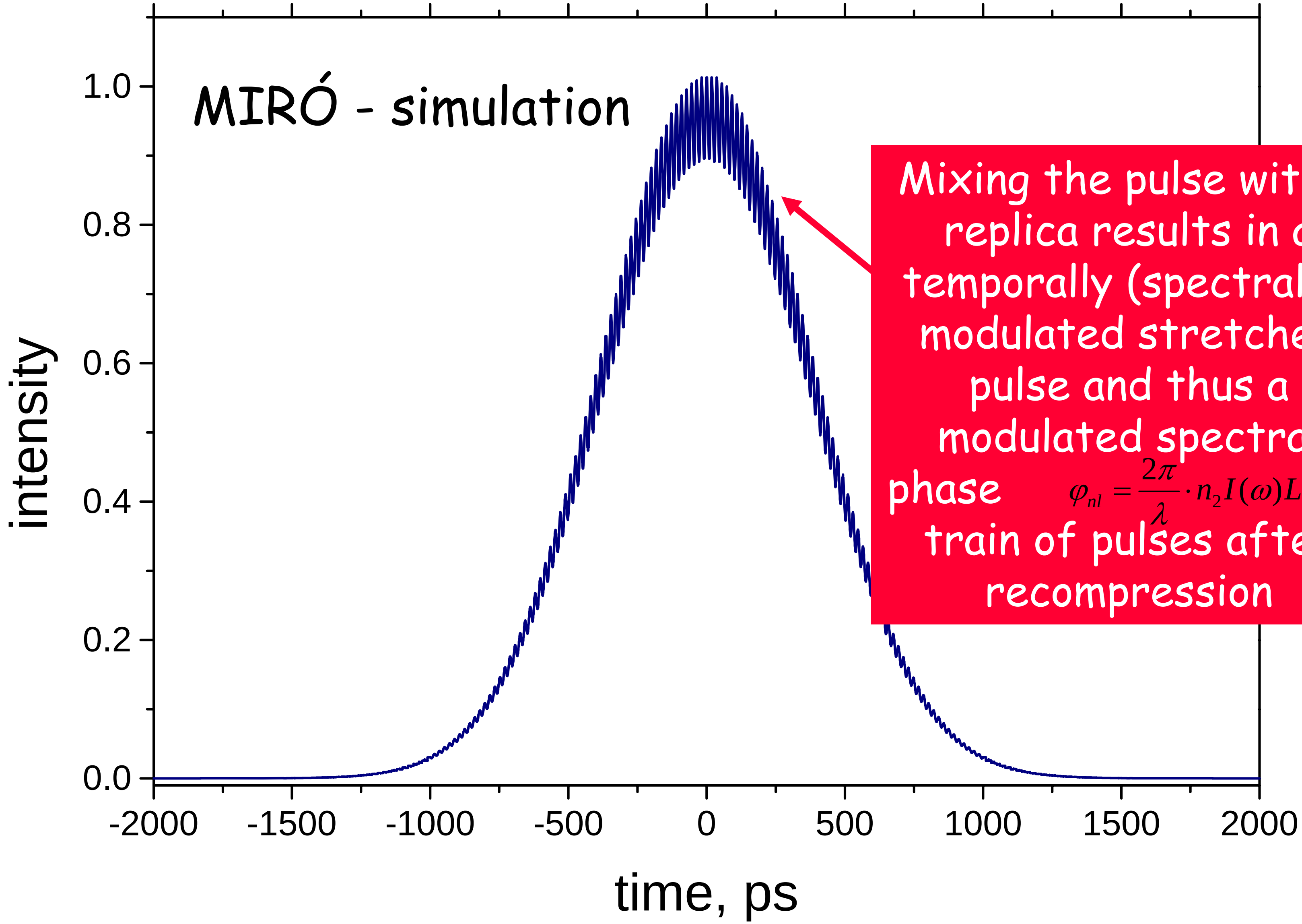
SPM with post-pulses

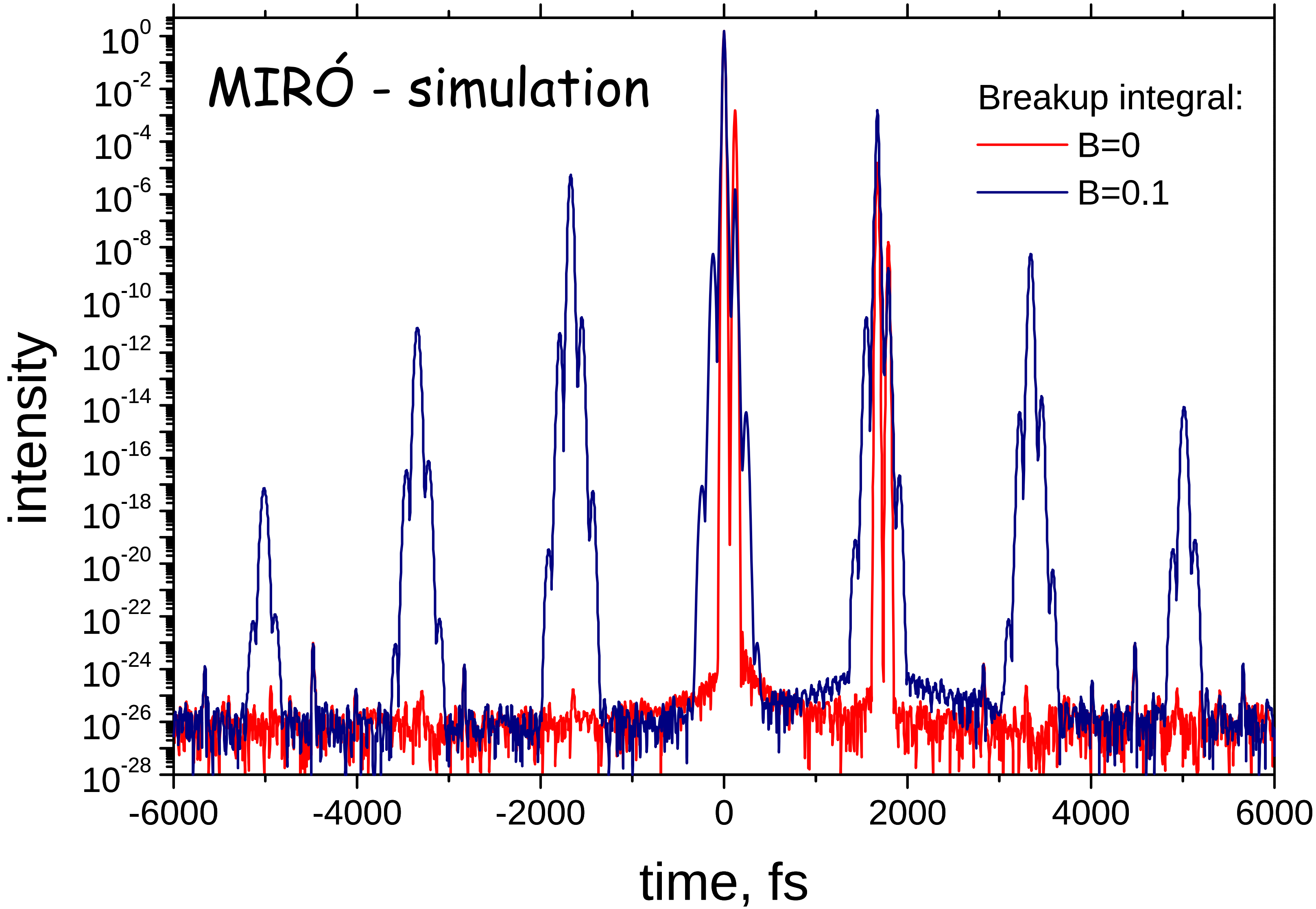


Stretched pulse mixed with a reflected replica



Mixing the pulse with a replica results in a temporally (spectrally) modulated stretched pulse and thus a modulated spectral phase $\varphi_{nl} = \frac{2\pi}{\lambda} \cdot n_2 I(\omega) L$ -> train of pulses after recompression

SPM with post-pulses



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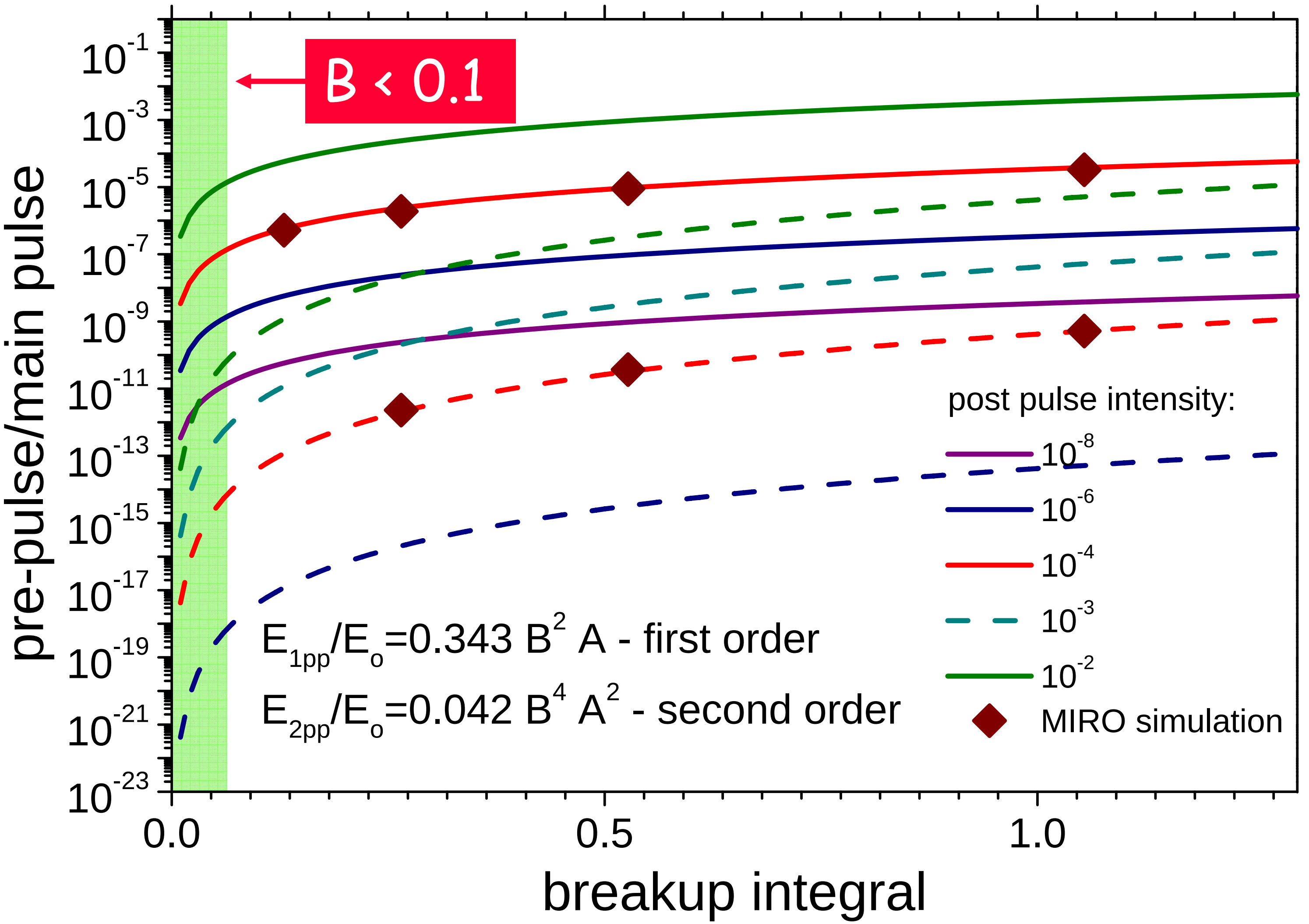
SPM, Pre-pulse energy



Conclusions

- the finite beam aperture ‚smoothes' strongly spectral clipping effects
- The ablation/melting limit (0.5J/cm^{2}) can be achieved at the time moment of several ps. before the pulse peak with diffraction gratings of a reasonable size. This can be a problem for intensity exceeding 10^{24}W/cm^{2}
- SPM of chirped pulses is a very important issue limiting temporal contrast