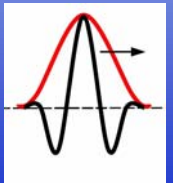
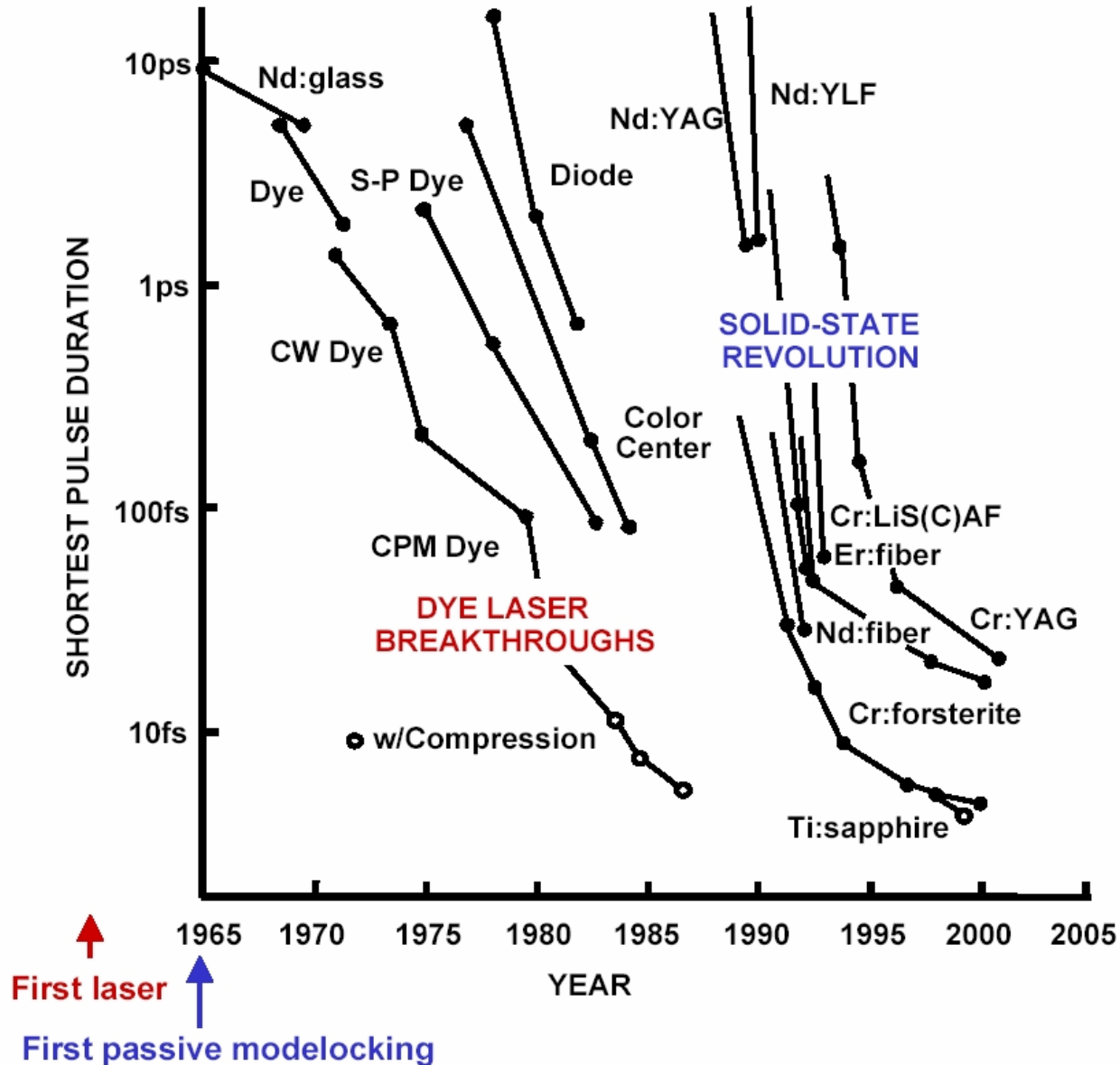


INTENSYVIŲ ŠVIESOS IMPULSŲ GENERACIJA KELIŲ OPTINIŲ CIKLŲ REŽIME

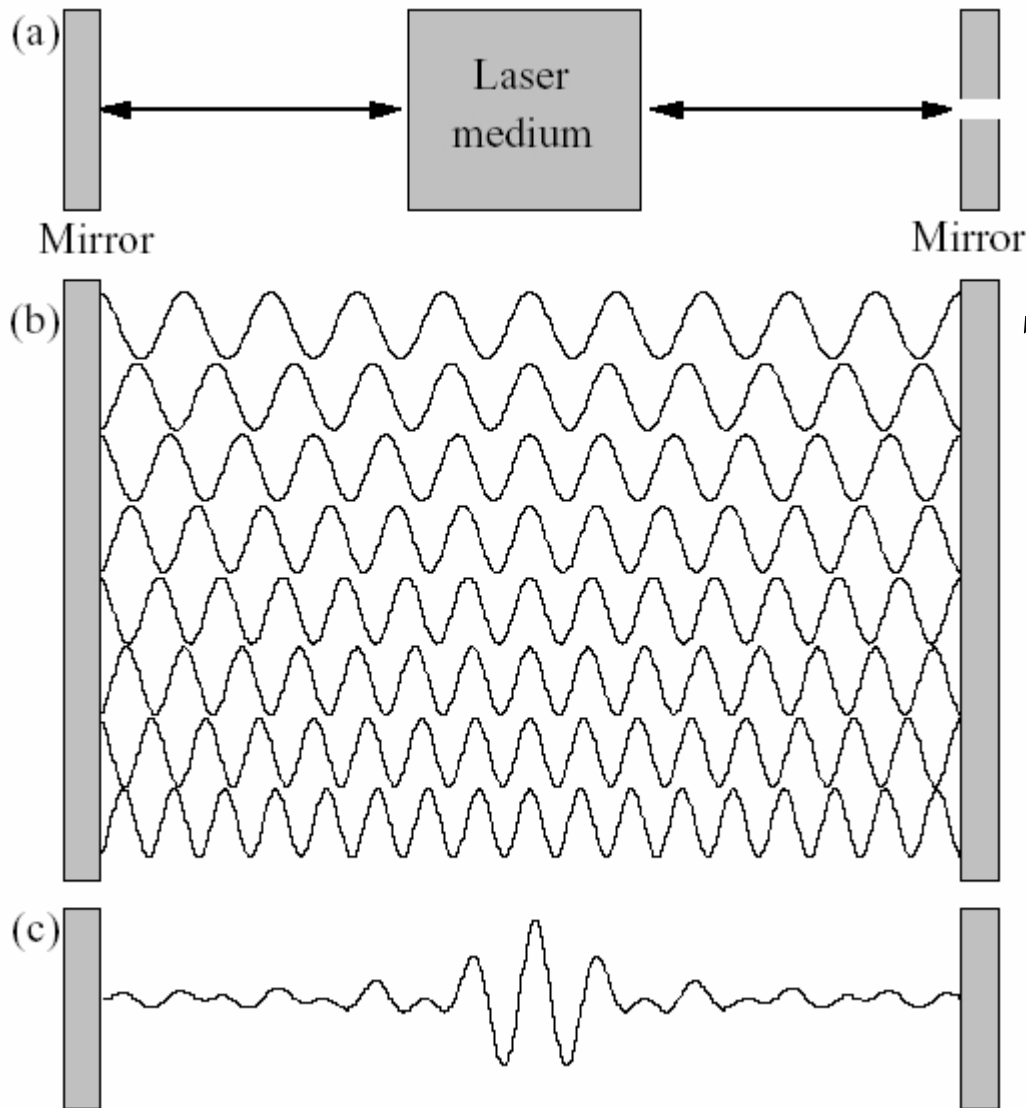
Viačeslav Kudriašov
2004 03 31



Ultratrumpųjų impulsų evoliucija



Modų sinchronizacijos principas



Faziškai surištos išilginės modos

Aktyvioji

Pasyvioji

su įsisotinančiu sugerikliu

su papildomu rezonatoriumi

Kero lęšio

Tipai

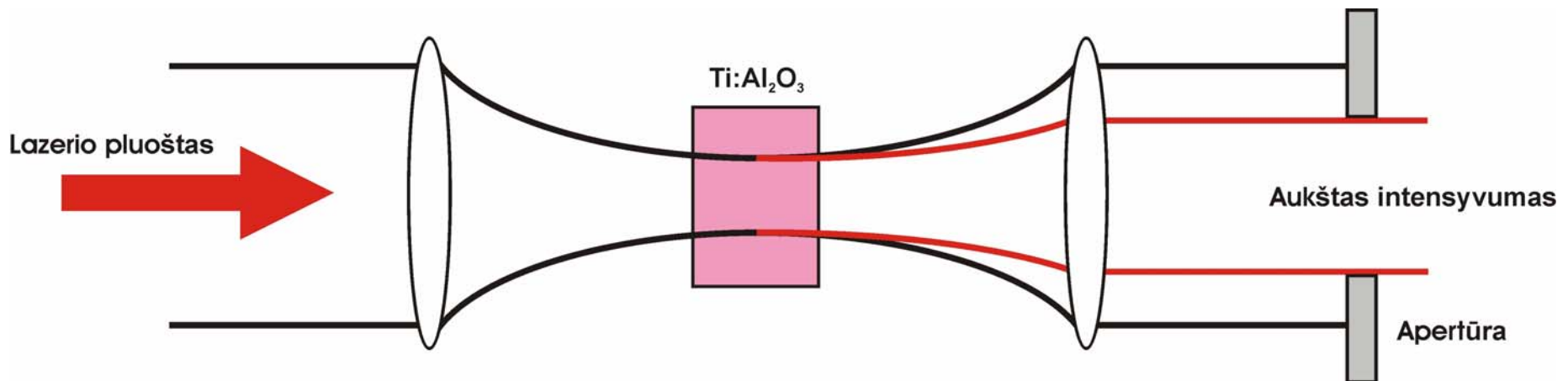
Kero lęšio modų sinchronizacija

$$n(r) = n_0 + \Delta n = n_0 + n_2 I(r) \quad \text{Netiesinis lęšis}$$

$$P_{kr} \propto \lambda^2 / n_2 \quad \text{Fokusavimo slenkstinė galia}$$

$$L_{SF} \sim \frac{k_0 \rho_0^2}{\sqrt{\frac{P(t)}{P_{kr}} - 1}} \quad \text{Fokusavimo atstumas} \\ \text{(priklauso nuo impulso momentinės galios!)}$$

Panaudojamas lazerio kristalo netiesiškumas



Medžiagos dispersija

Dispersija $n = n(\omega) \longrightarrow$ Spektrinių komponentų išsifazavimas

Grupinis vėlavimas GDD
(group delay dispersion)

$$T_g(\omega) = \frac{\partial \phi(\omega_0)}{\partial \omega} = \frac{L}{c} \frac{\partial}{\partial \omega}(\omega n)$$

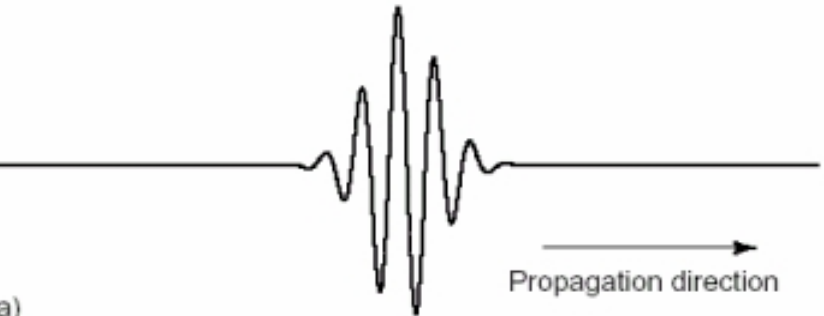
Grupinio greičio dispersija



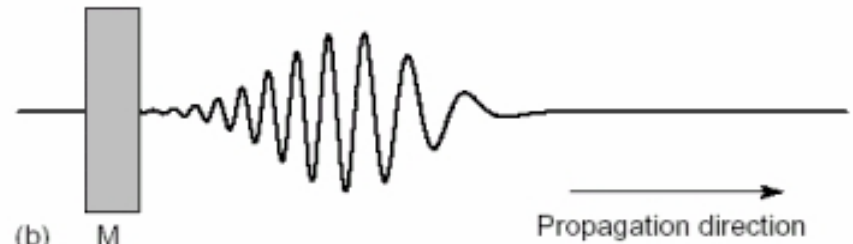
$$T_g(\omega) = \phi'(\omega_0) + \phi''(\omega_0)(\omega - \omega_0) + \frac{1}{2} \phi'''(\omega_0)(\omega - \omega_0)^2$$

$$+ \frac{1}{6} \phi''''(\omega_0)(\omega - \omega_0)^3 + \dots$$

4-os eilės dispersija



(a)



(b)

3-os eilės dispersija

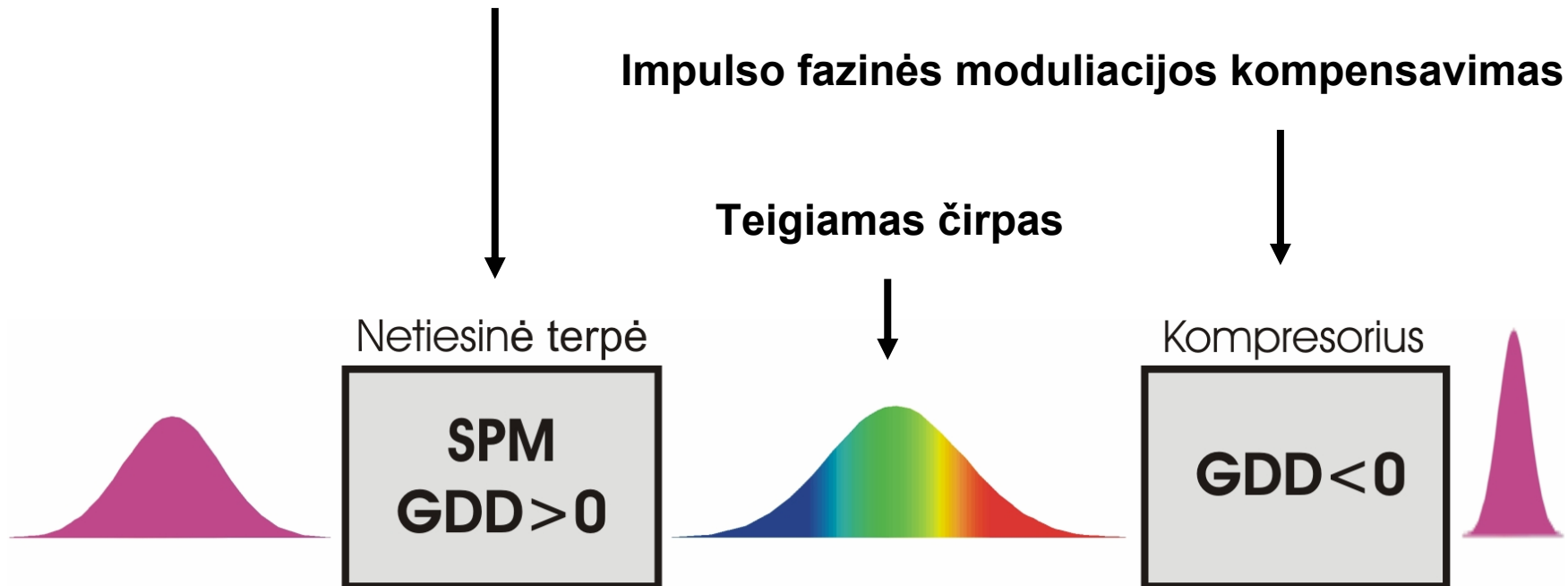
Optinių impulsų kompresijos principas

$$n(t) = n_0 + n_2 I(t) \quad \text{Optinis Kero efektas}$$

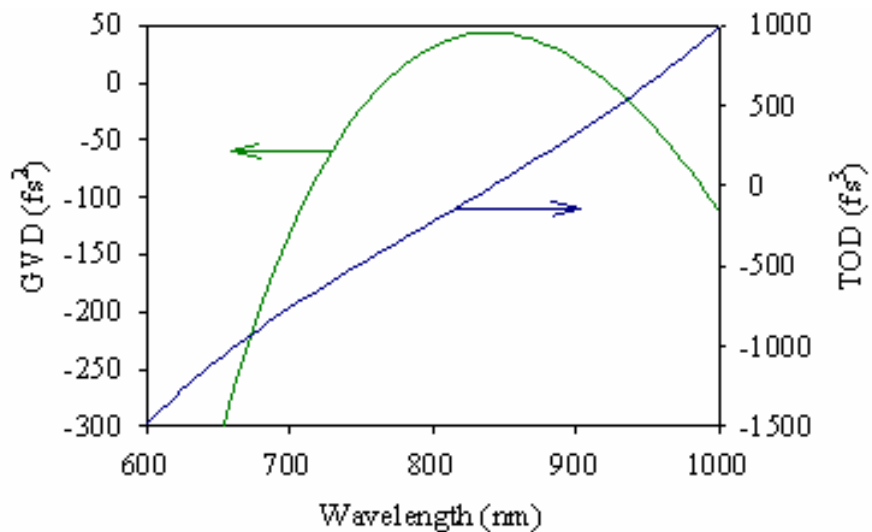
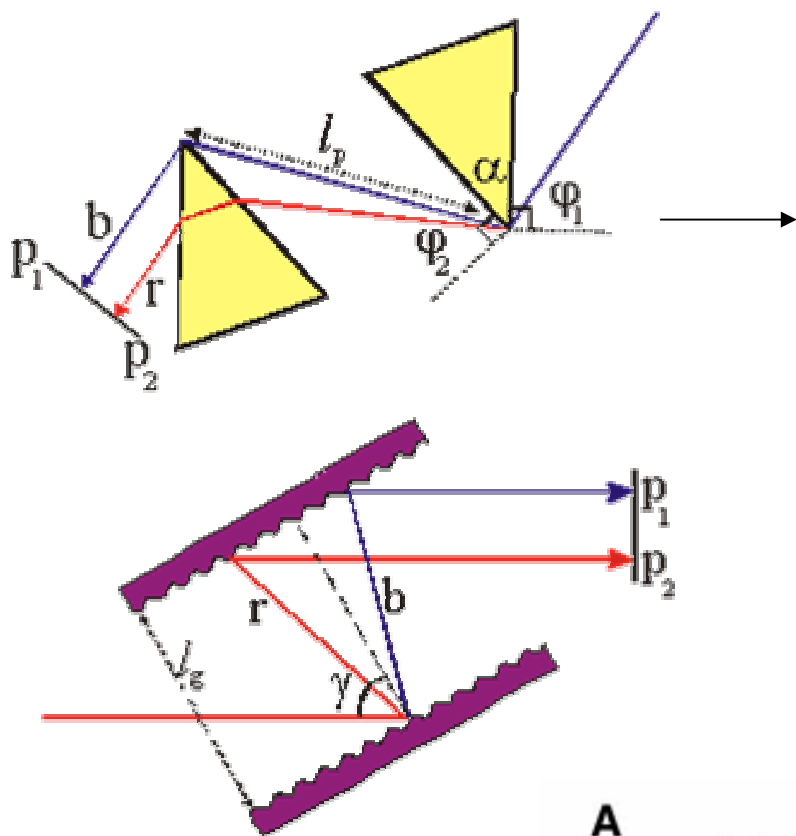
$$\Delta\omega(t) = \frac{\partial\Delta\varphi(t)}{\partial t} \propto -\frac{\partial I(t)}{\partial t} \quad \text{Dažnio pokytis} \longleftarrow \text{Fazinė savimoduliacija}$$

Spektro išplitimas dėl fazinės savimoduliacijos

Impulso fazinės moduliacijos kompensavimas

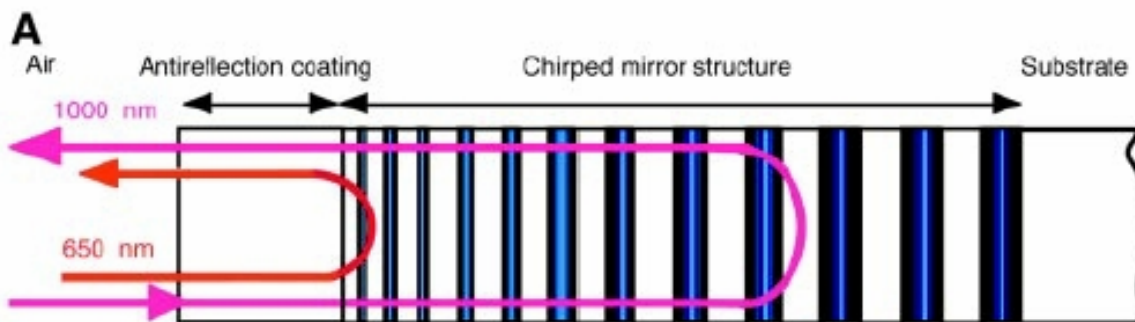


Neigiamos GDD realizavimas

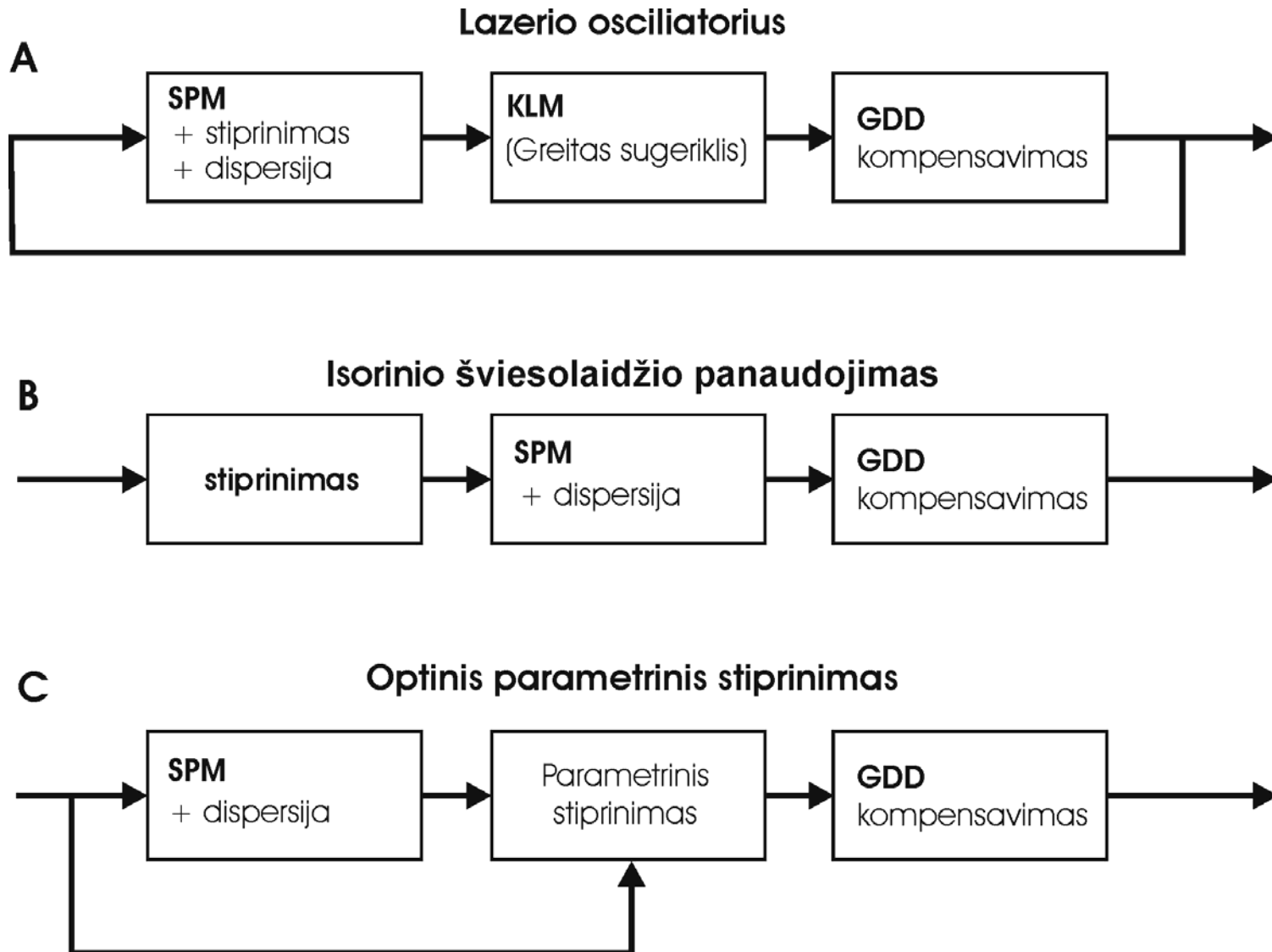


GVD ir TOD kompensavimas lazerio rezonatoriuje

Čirpuotas veidrodis



Kelių ciklų impulsų generavimo schemas

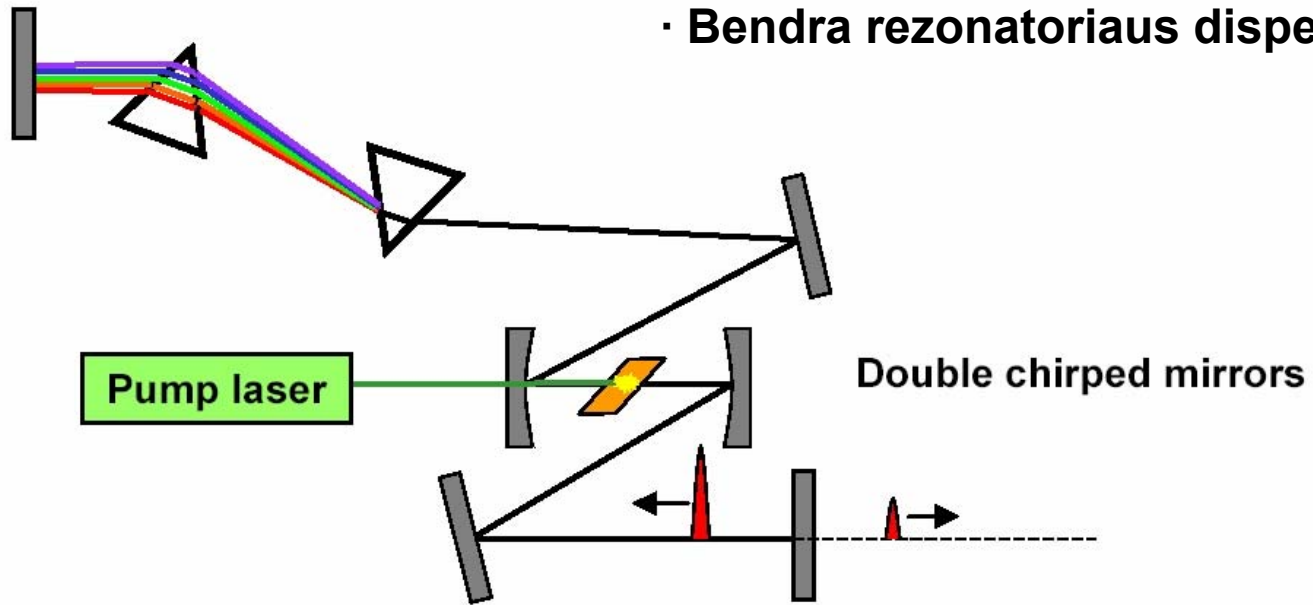


Generacija lazerio rezonatoriuje

The 5-fs Ti:sapphire Laser

- Kerr-lens modelocking

- Kero lęšio modų sinchronizacija
- Fazinė savimoduliacija
- Bendra rezonatoriaus dispersija

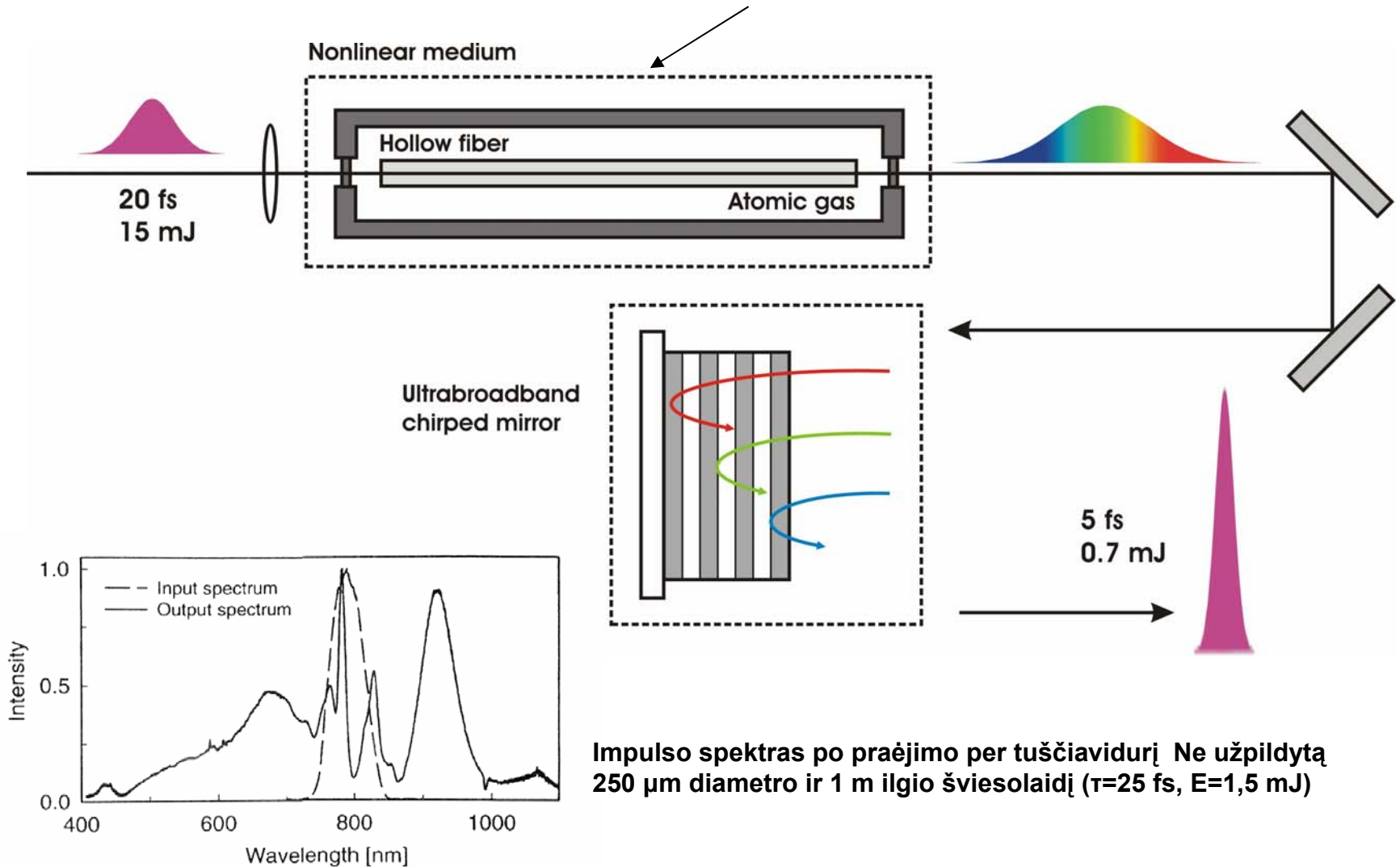


Stretched-pulse modelocking

Pulse durations shorter than 2-cycles

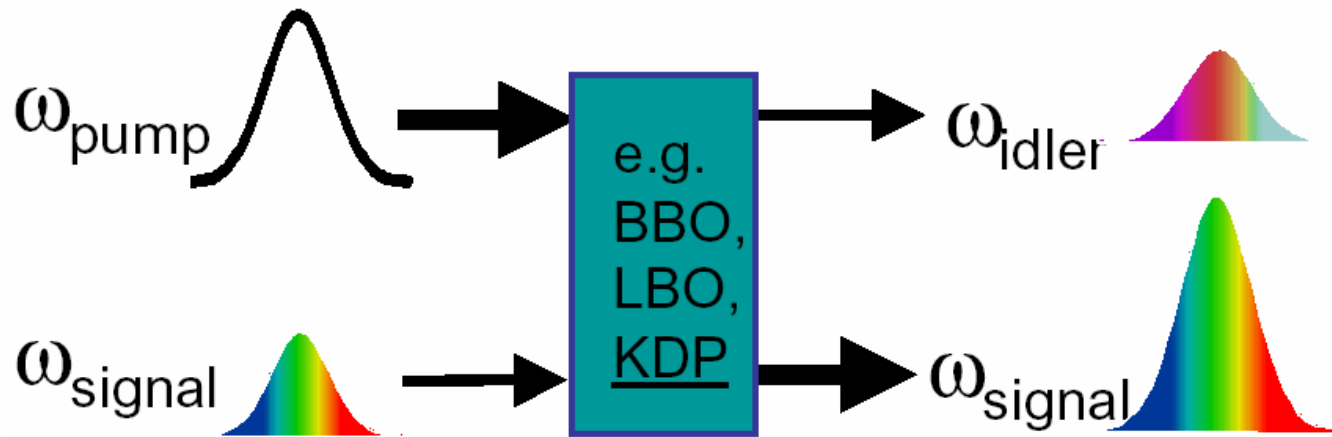
Išorinė impulsų kompresija

Tuščiaviduris šviesolaidis



Impulso spektras po praėjimo per tuščiaidurį Ne užpildytą 250 μm diametro ir 1 m ilgio šviesolaidį ($\tau=25$ fs, $E=1,5$ mJ)

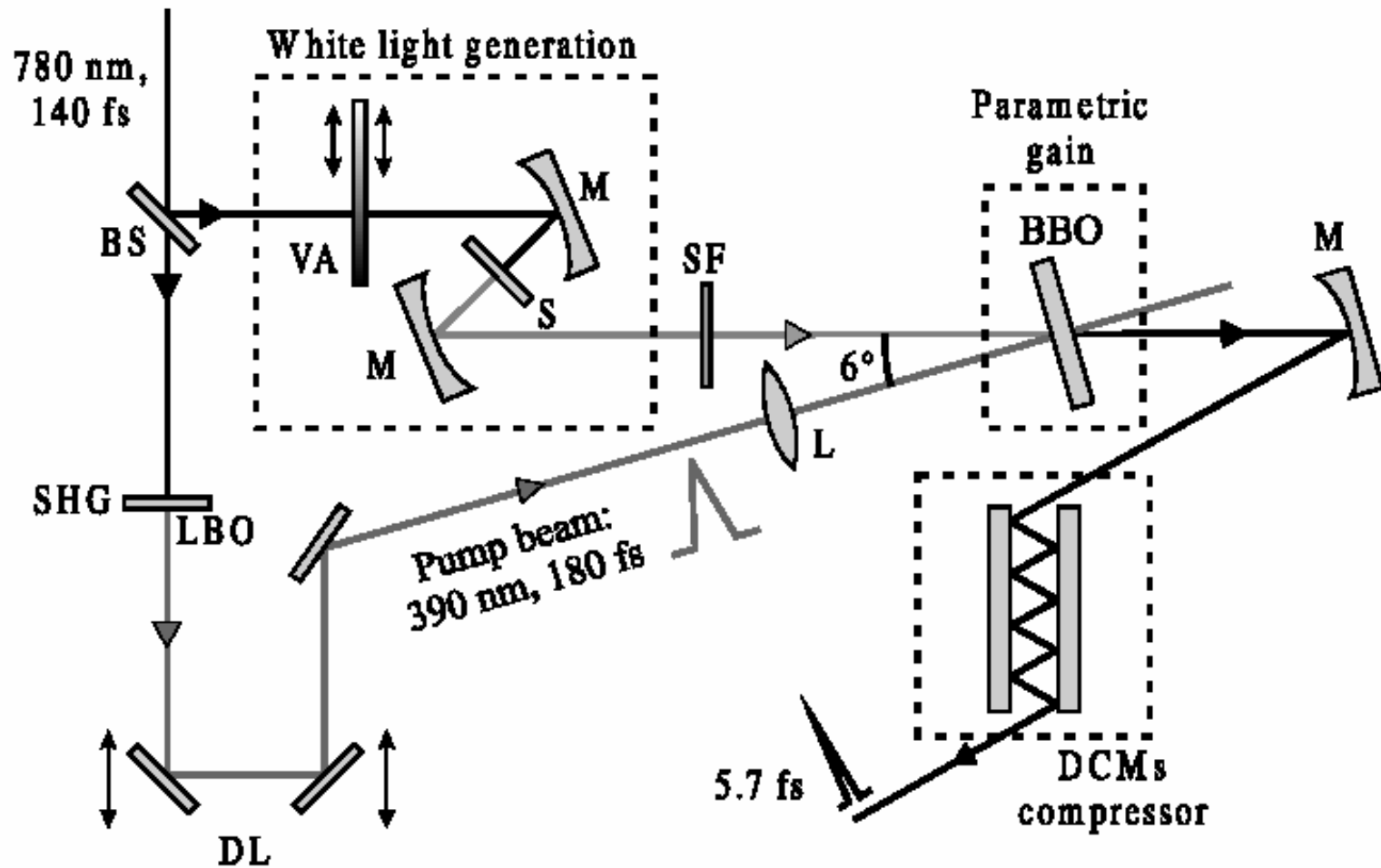
Parametrinio stiprinimo metodos



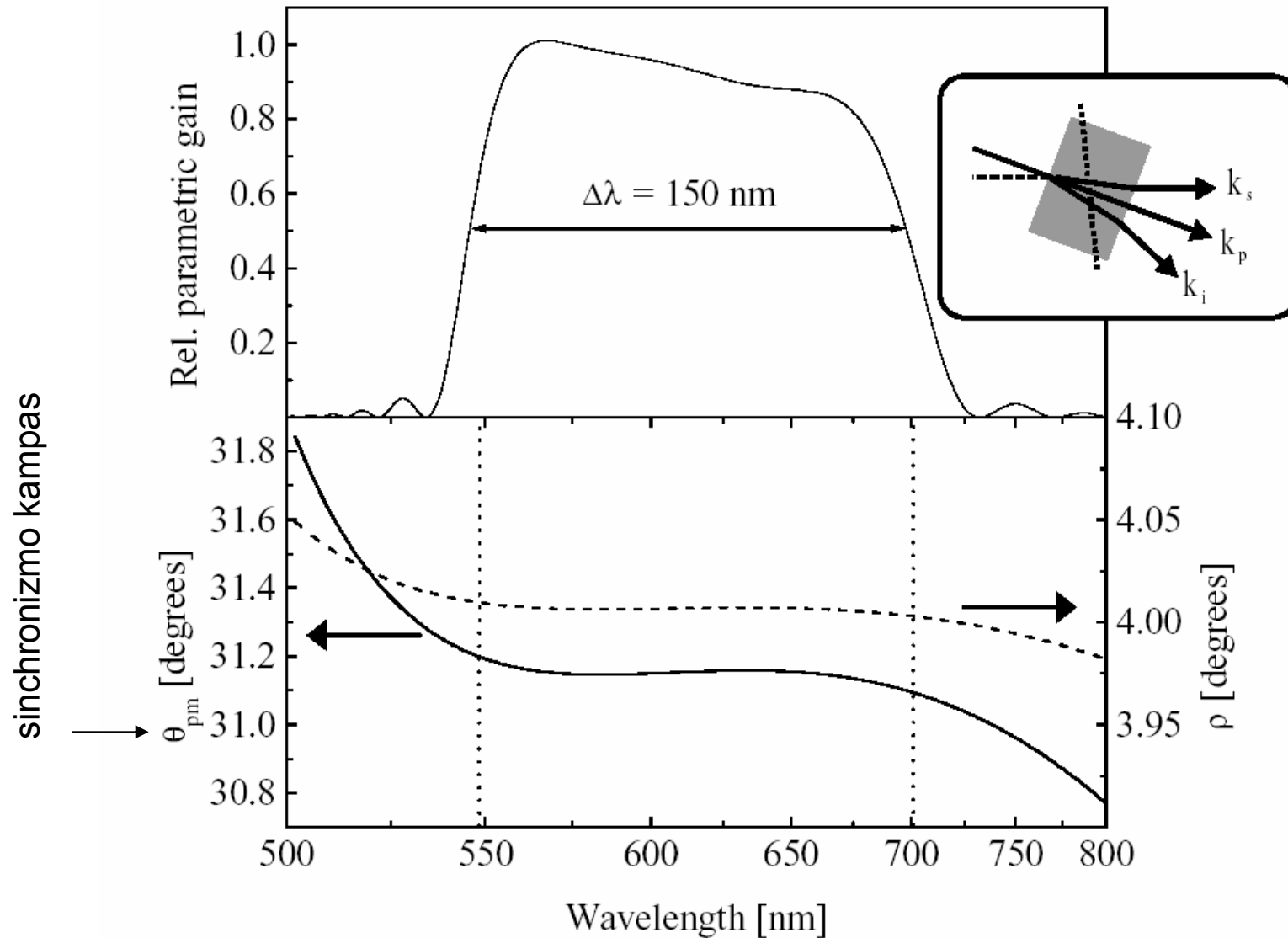
$$\omega_{\text{pump}} = \omega_{\text{signal}} + \omega_{\text{idler}}$$

$$\vec{k}_{\text{pump}} = \vec{k}_{\text{signal}} + \vec{k}_{\text{idler}}$$

Nekolinarus parametrinis stiprinimas



Nekolinarus parametrinis stiprinimas

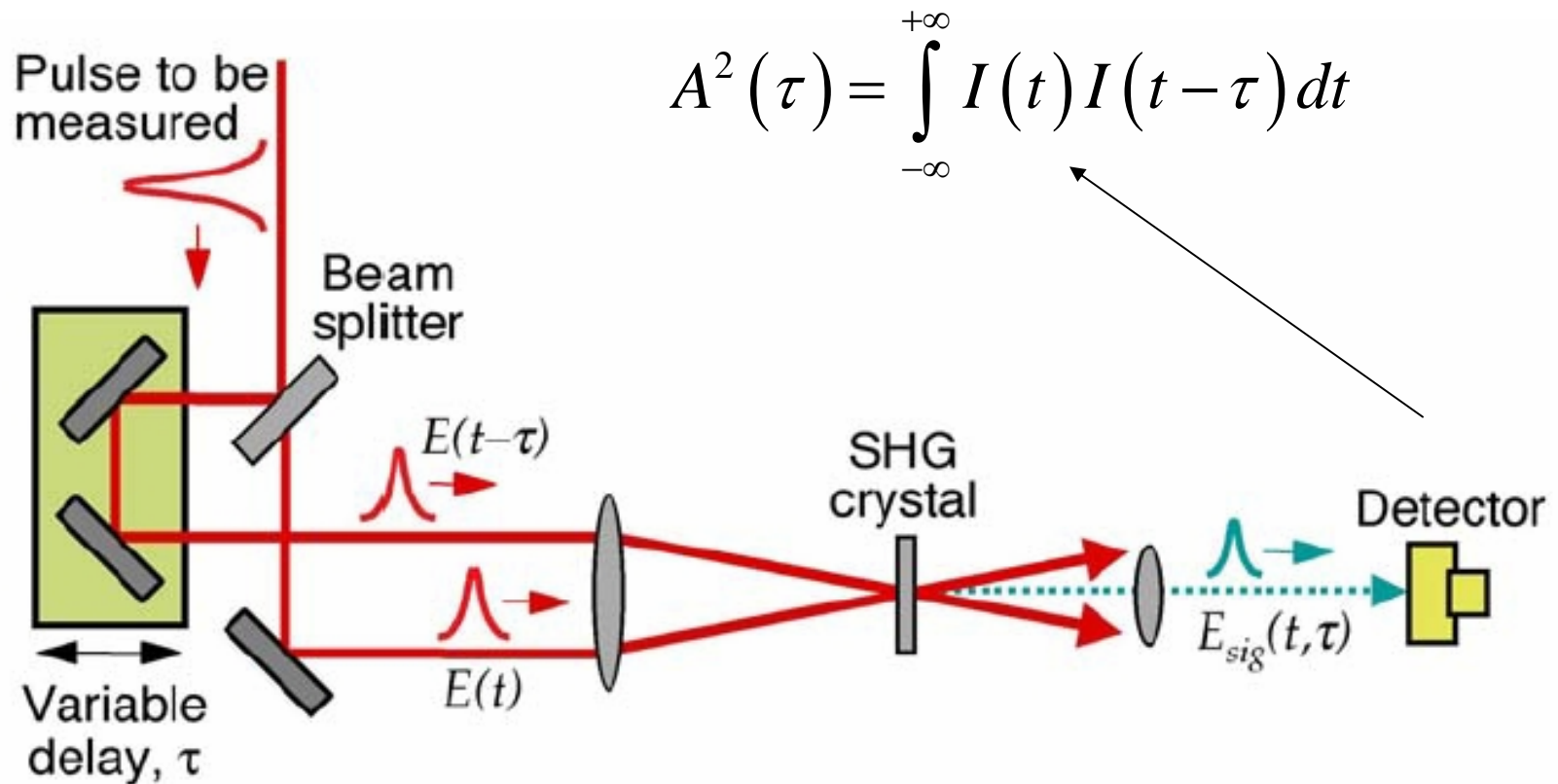


Metodų palyginimas

| Technique | Shortest pulse FWHM, fs | Pulse energy, mJ | Repetition rate, kHz | Advantages | Disadvantages |
|---|-------------------------|------------------------|----------------------|--|---|
| Ti:sapphire oscillators | <6 | $\sim 2 \cdot 10^{-6}$ | 10^5 | Simplicity, low cost, reliability | Fixed wavelength [‡] . Difficult rep. rate reduction |
| Cavity dumped Ti:sapphire laser + quartz fiber | <5 | $\sim 10^{-5}$ | 1–1000 | Flexible rep. rate control. Higher energy and broader spectrum than oscillators. | Fixed wavelength [‡] |
| Hollow-fiber pulse compression | <5 | 0.5 | ~ 1 | Very high intensities suitable for variety of strong field applications | Requires laser amplifiers. Rep. rate determined by pump lasers. |
| Noncollinear optical parametric amplifiers [†] | <5 | 10^{-3} | ~ 1 | Tunable pulses | Requires laser amplifiers. Rep. rate determined by pump lasers. High complexity |

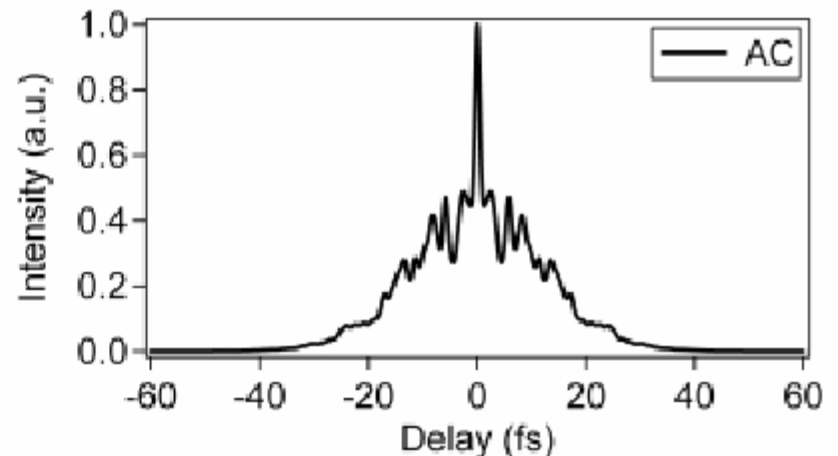
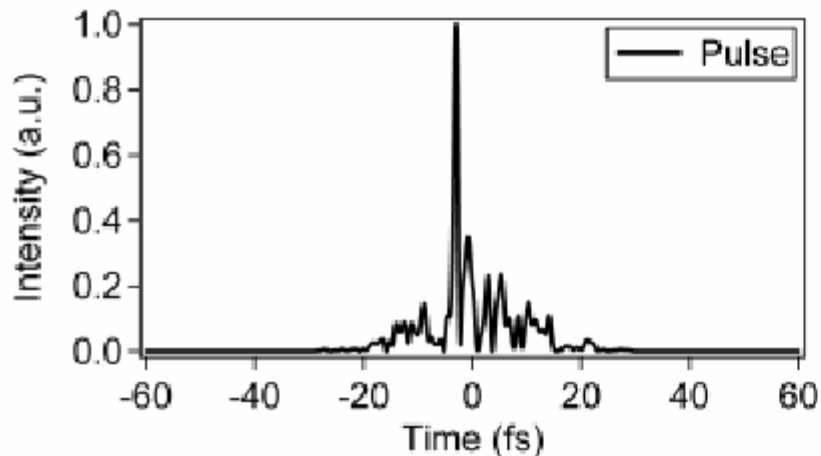
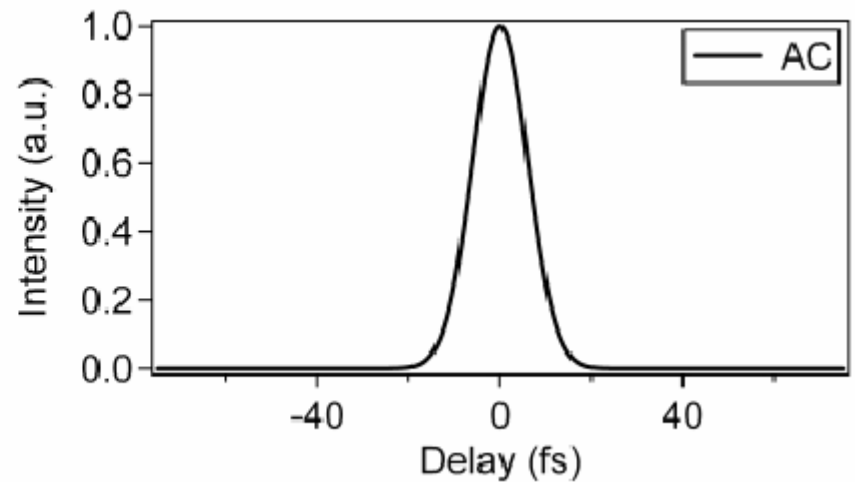
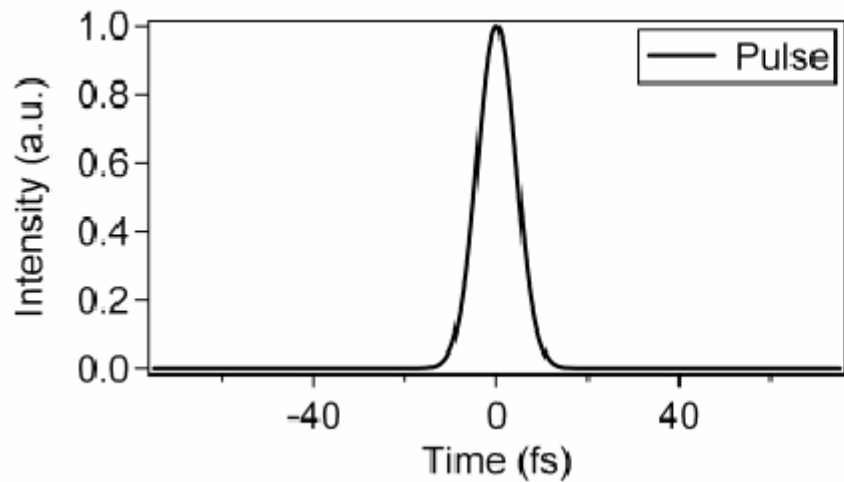
Ultratrumpųjų impulsų charakterizavimas

Autokoreliacinis metodas

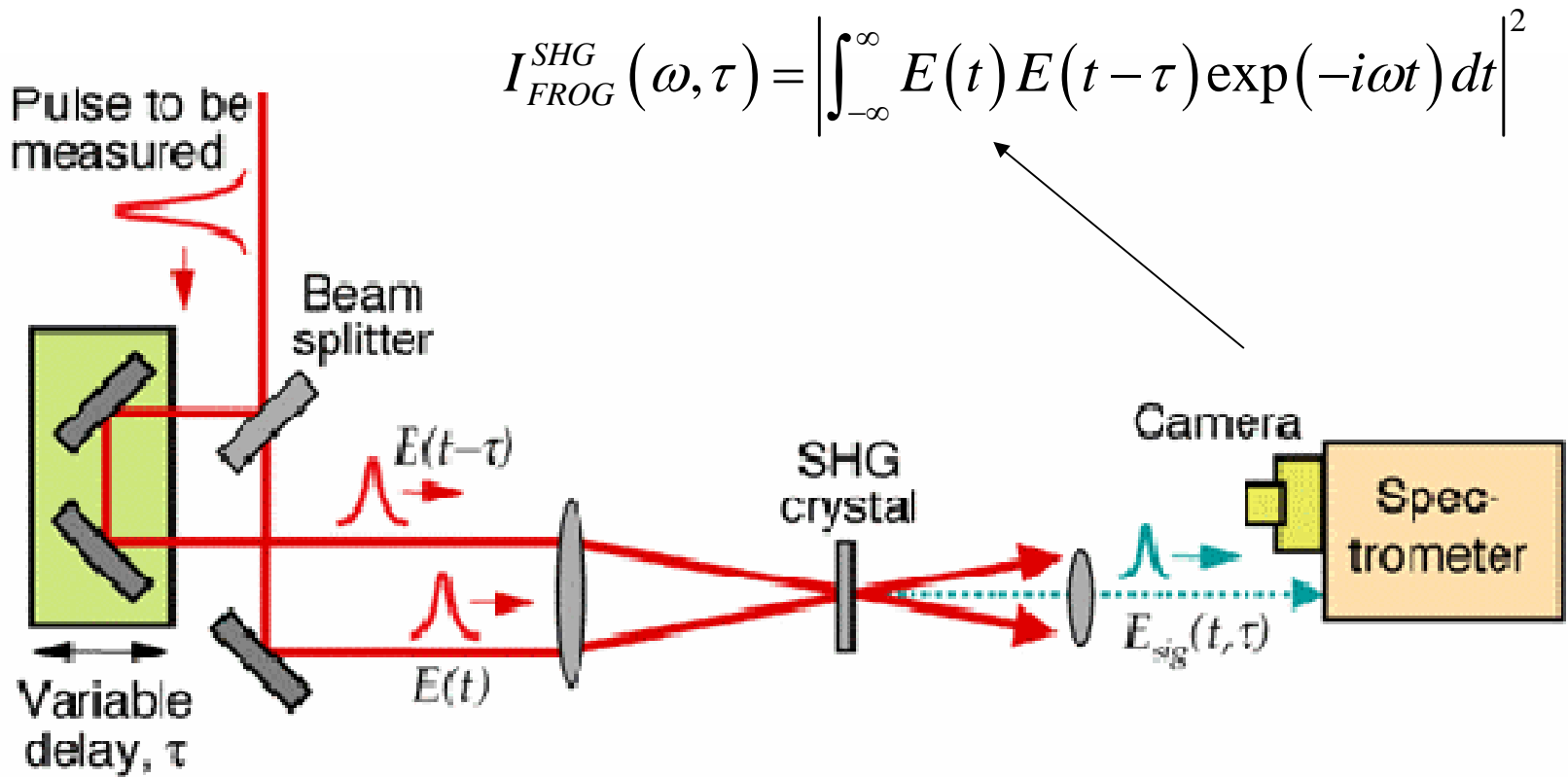


Ultratrumpųjų impulsų charakterizavimas

Autokoreliacinis metodas

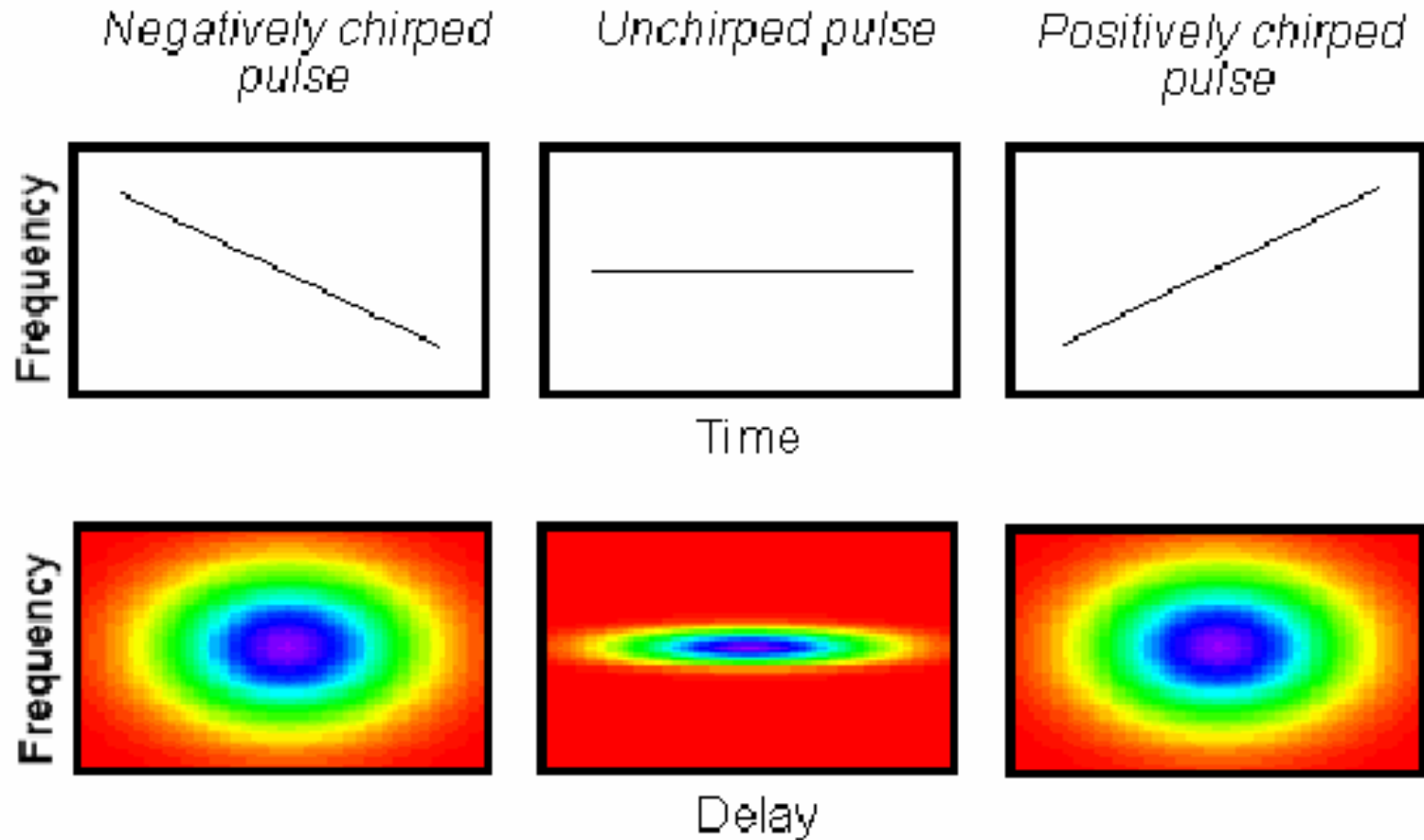


FROG (Frequency-Resolved Optical Gating) metodus



FROG (Frequency-Resolved Optical Gating) metodas

Spektrogramų pavyzdžiai



FROG (Frequency-Resolved Optical Gating) metodus

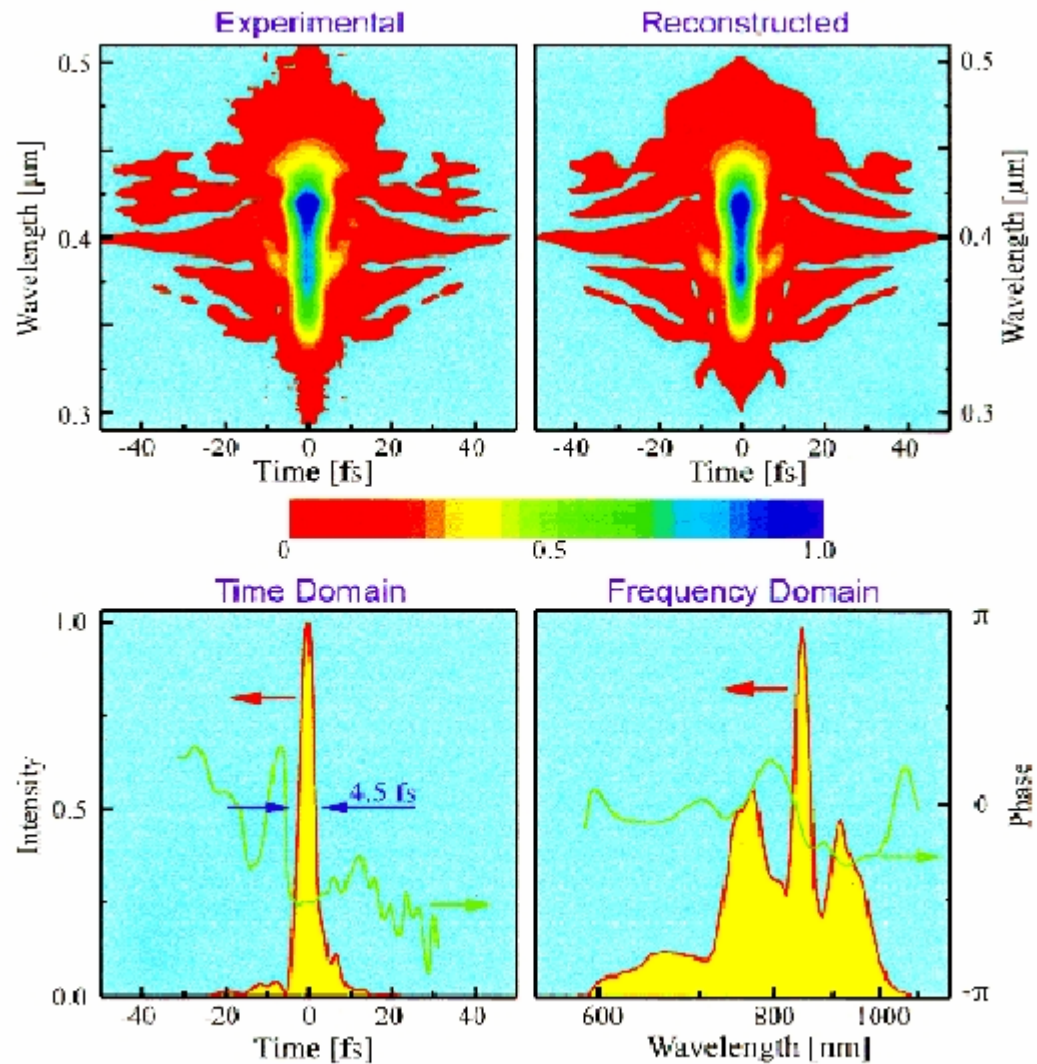
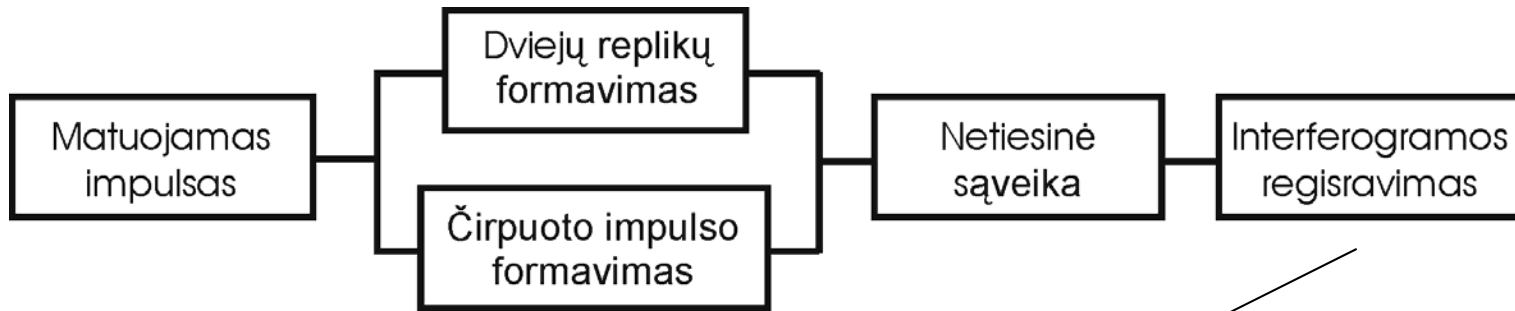


Fig. 8. One of the shortest events ever measured, a 4.5-fs pulse, measured using SHG FROG. Baltuska, Pshenichnikov, and Weirsmas, J. Quant. Electron., 35, 459 (1999).

SPIDER (Spectral Phase Interferometry for Direct Electric-field Reconstruction) metodas



$$\tilde{S}(\omega) = \tilde{I}(\omega) + \tilde{I}(\omega + \Omega) +$$

$$2\sqrt{I(\omega)}\sqrt{I(\omega + \Omega)} \cos(\phi(\omega) - \phi(\omega + \Omega) + \omega\tau)$$

