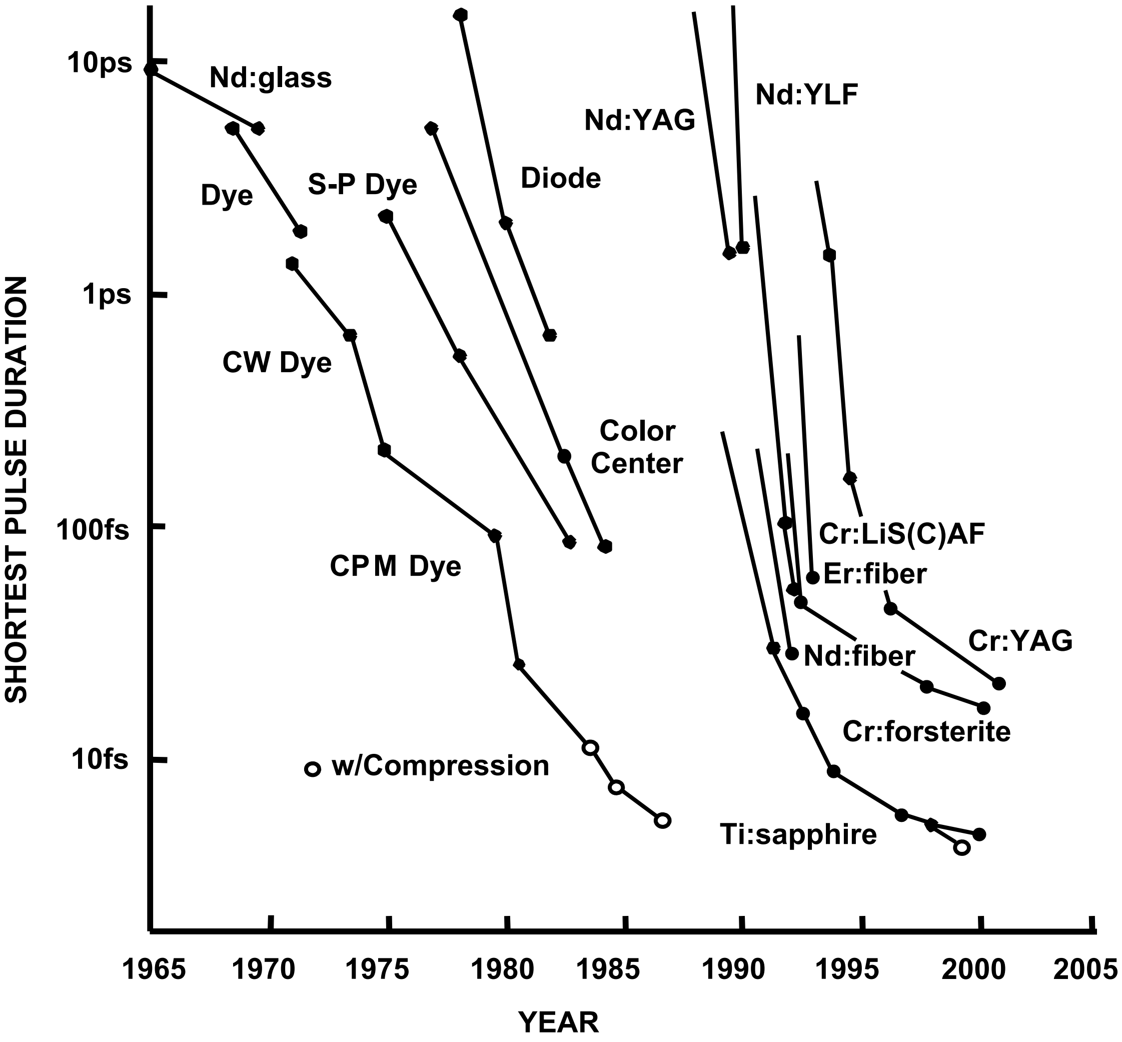
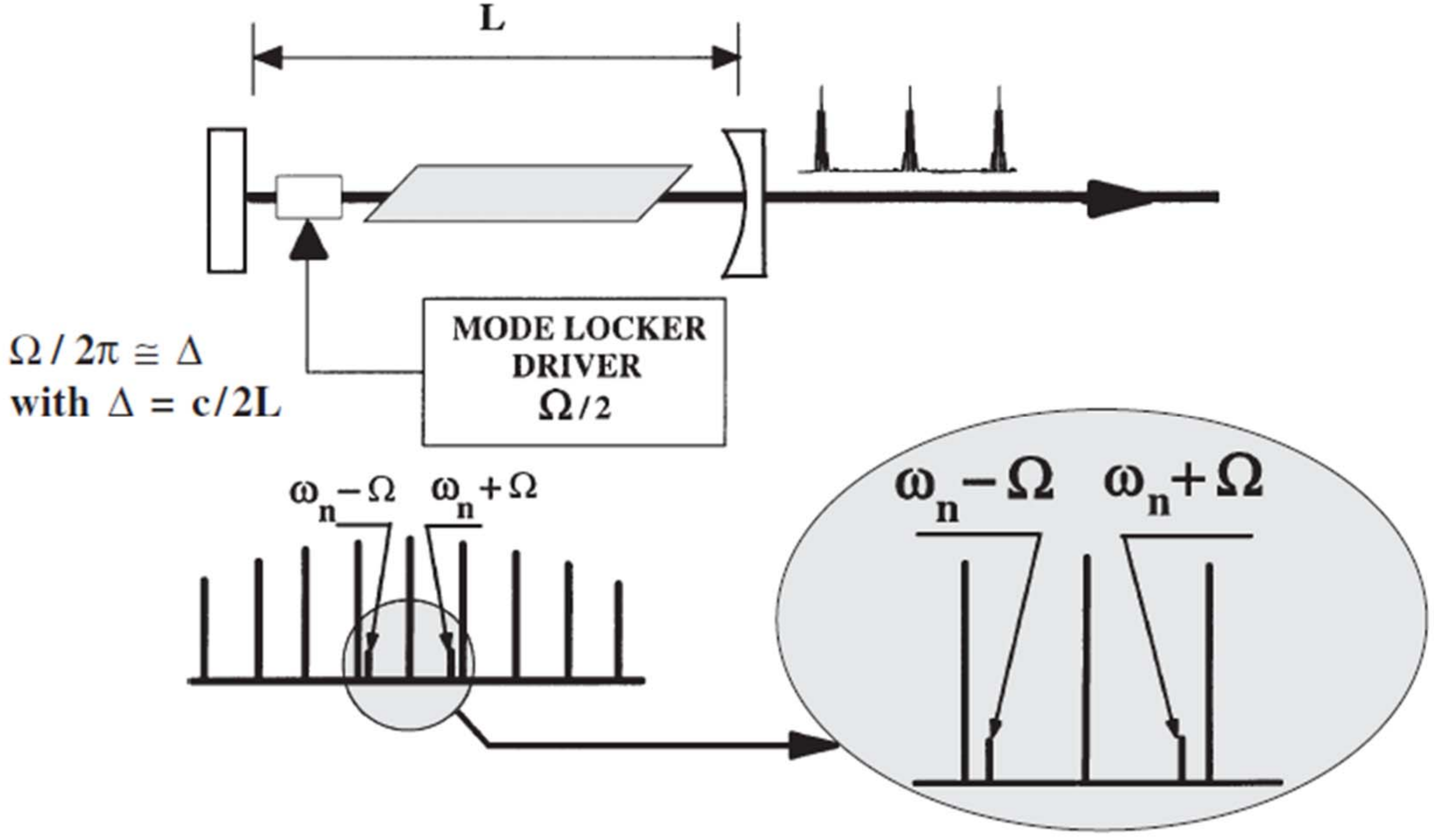
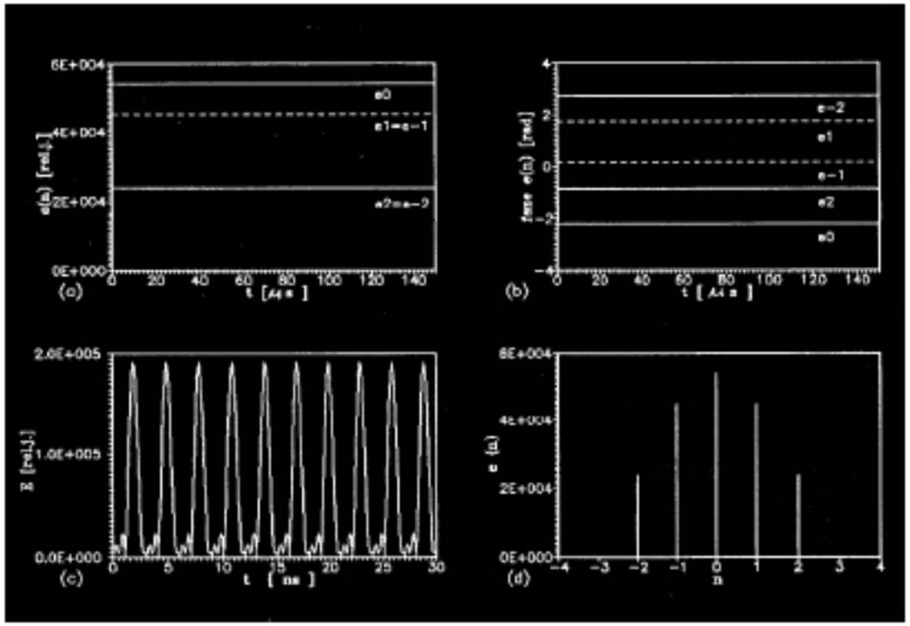
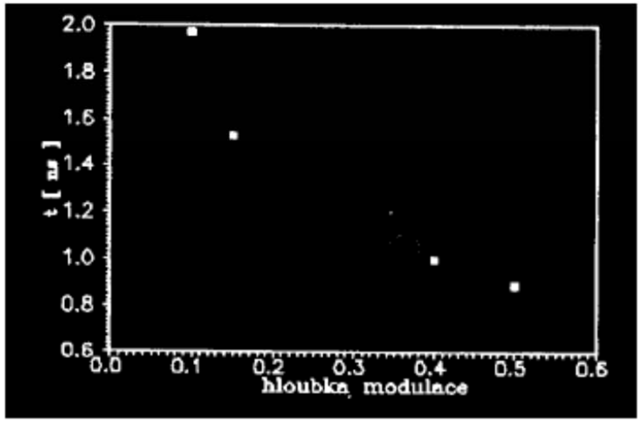

10ps
1ps
100fs
10fs
SHORTEST PULSE DURATION
1965
1970
1975
1980
1985
1990
1995
2000
2005
YEAR
Nd:glass
Dye
S-P Dye
Diode
Nd:YAG
Nd:YLF
CW Dye
Color Center
CPM Dye
w/Compression
Cr:LiS(C)AF
Er:fiber
Cr:YAG
Nd:fiber
Cr:forsterite
Ti:sapphire



Aktivní ML

MODEL: 5 modes, Maxwell-Bloch equations (29 diff Eqs.)

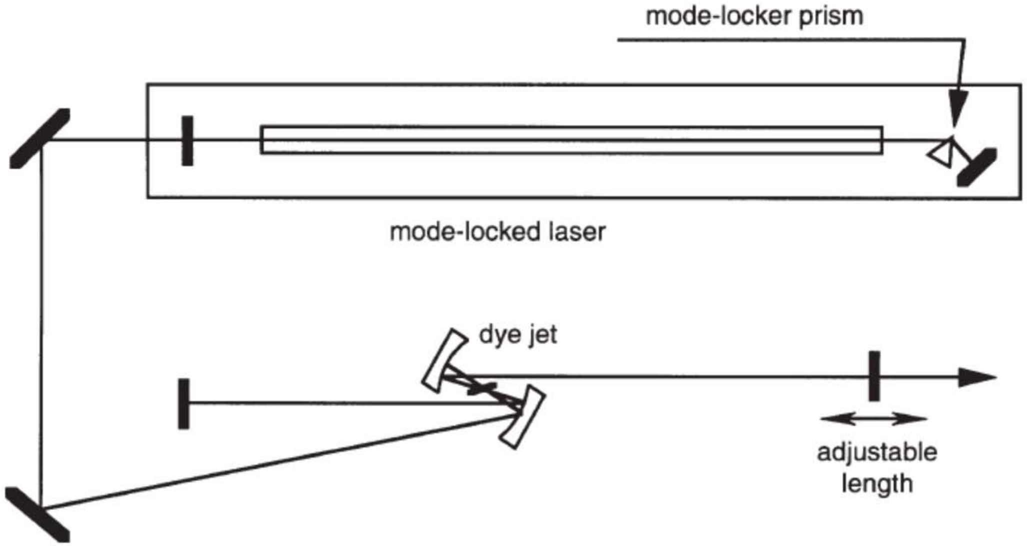




LOSS MODULATION:

$1/t_c = K (1 + \theta \cos \omega t)$

LASER Co: MgF$_2$, θ = 0.5



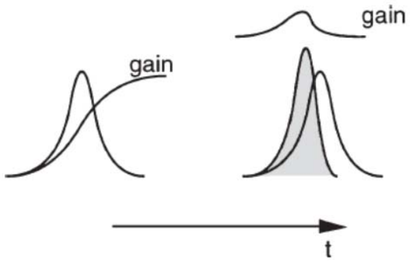
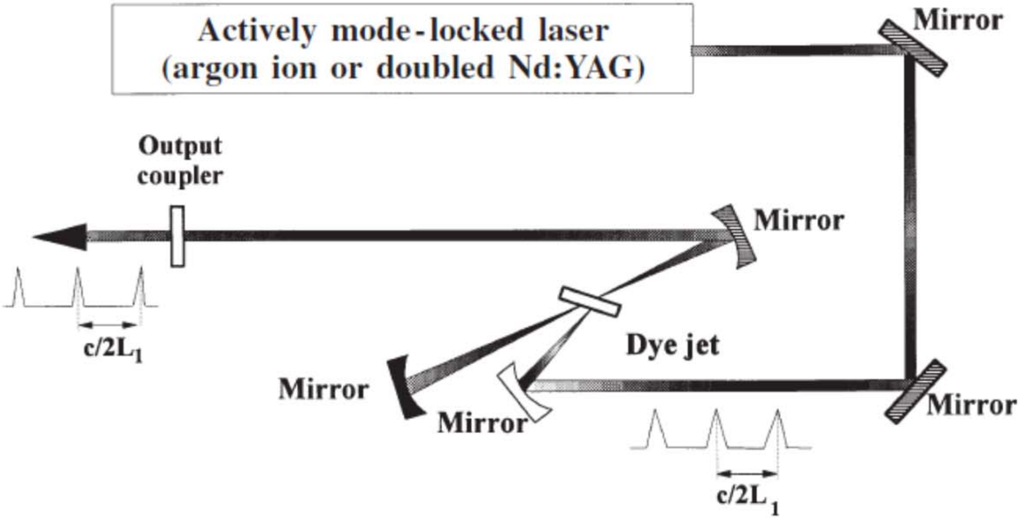


Fig. 4.6. Pulse shortening through gain saturation. *Left*, the time envelope of the pump pulses and the corresponding gain increase in the dye (in arbitrary normalized units). *Right*, result of the synchronized propagation of the dye oscillator pulse through the gain medium. The leading part of the pulse is strongly amplified up to the point when the gain saturates. The trailing part is not amplified, which results in a narrowing of the pulse [4.23–24]

Synchronní čerpání



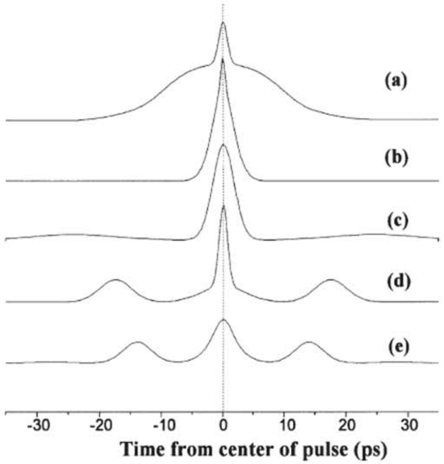
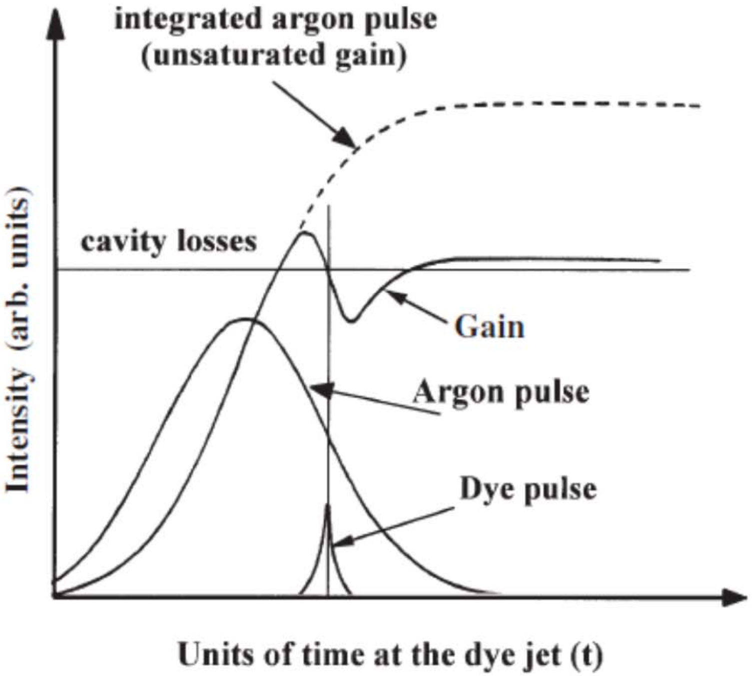
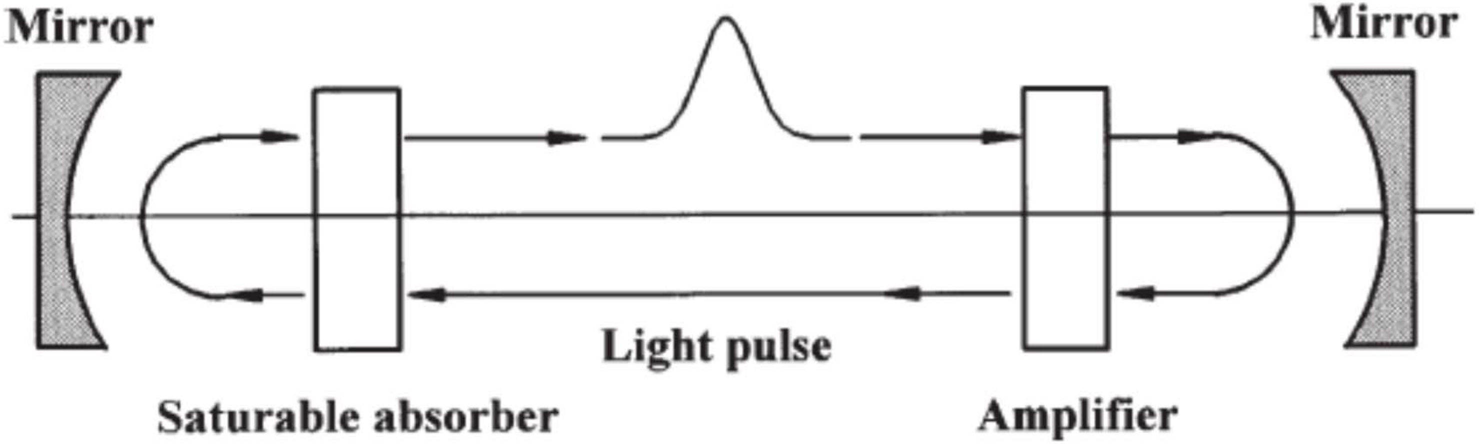


Fig. 3.11. Autocorrelation curve shape as a function of the mismatch between the cavity optical lengths of the pump laser and of the pumped laser (see text)





Pasivní ML

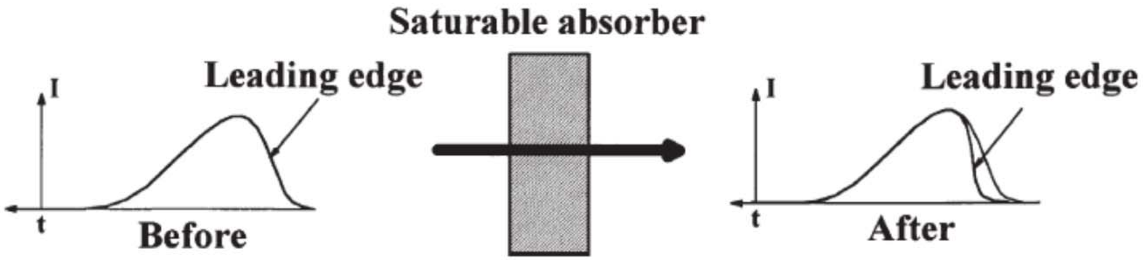


Fig. 3.15. Illustration of pulse shape modification after crossing a saturable absorber

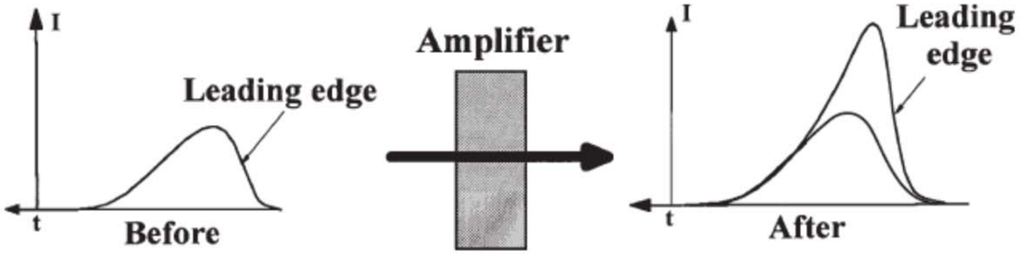
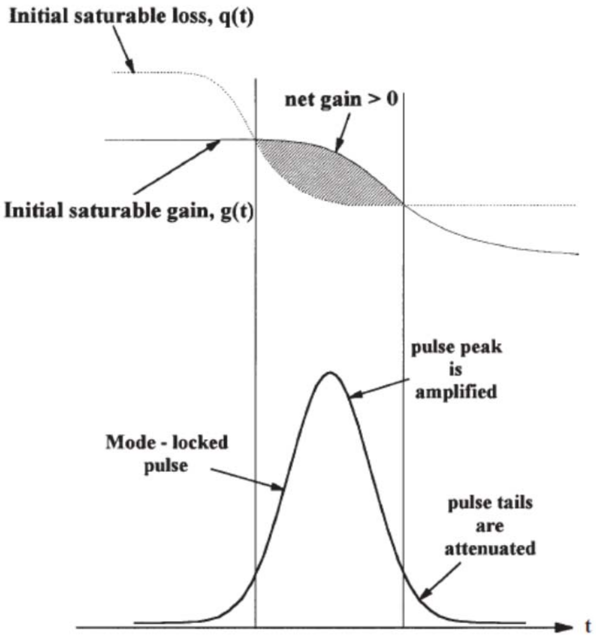
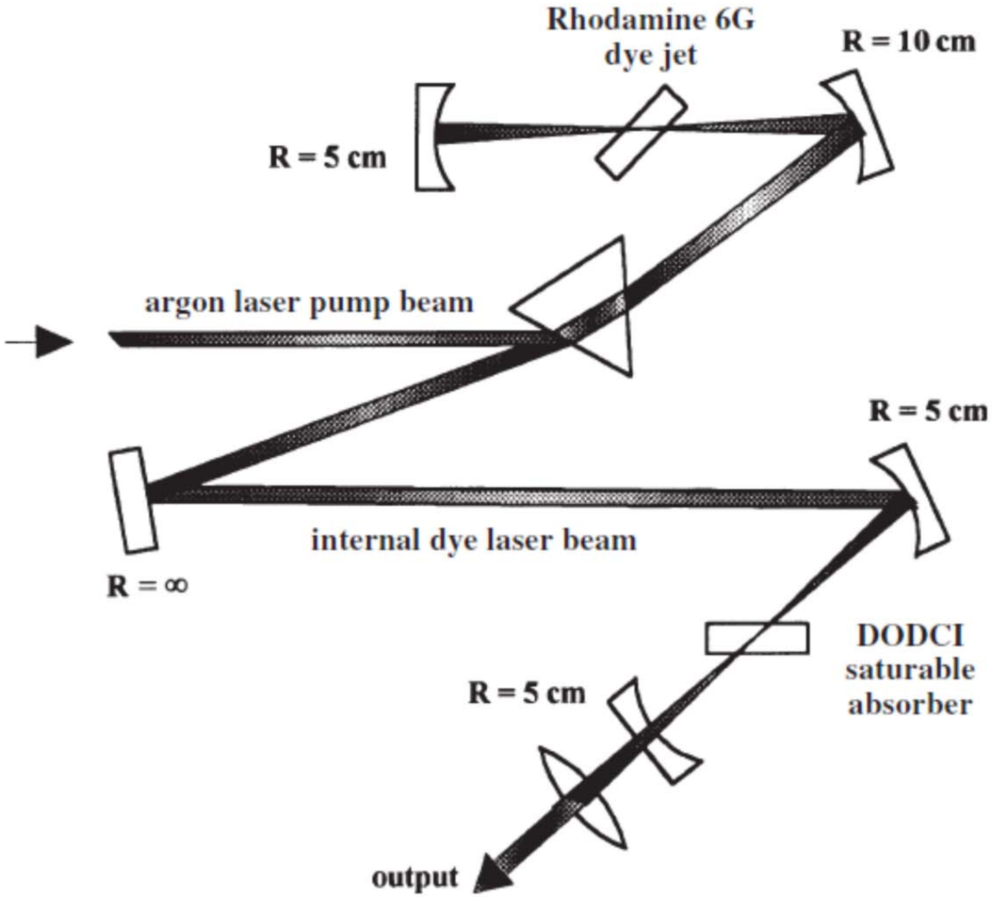
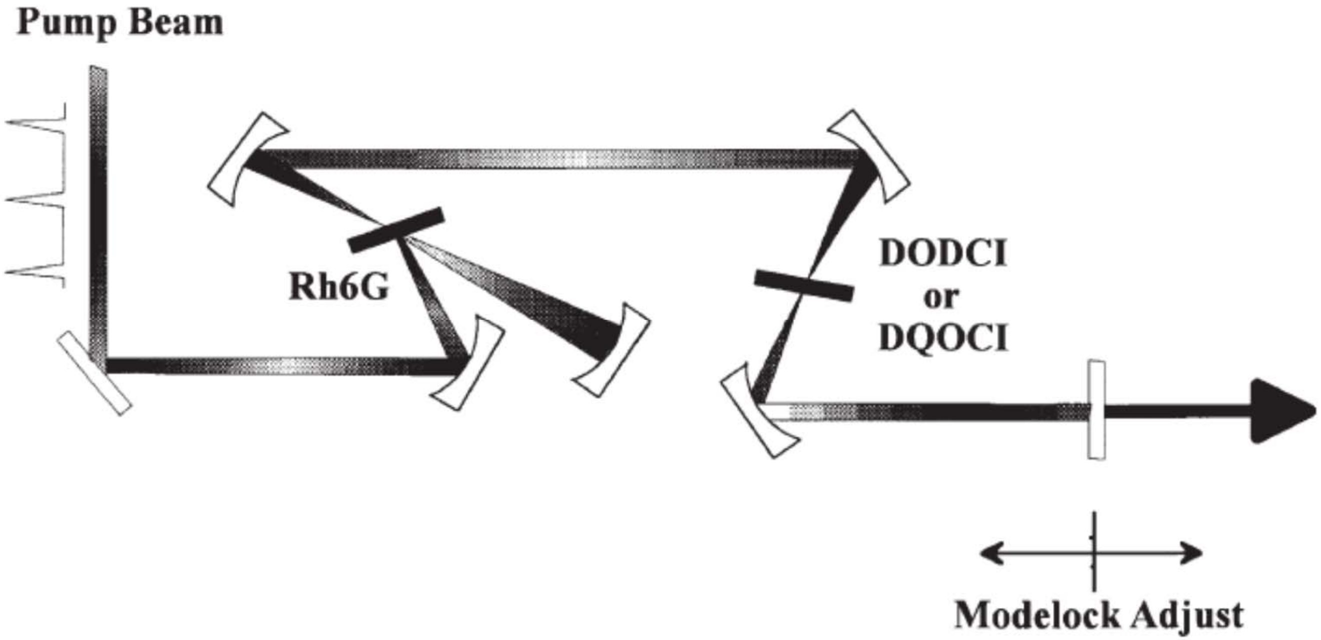


Fig. 3.16. Illustration of pulse shape modification after crossing an amplifying medium


Initial saturable loss, q(t)
net gain > 0
Initial saturable gain, g(t)
pulse peak
is
amplified
Mode - locked
pulse
pulse tails
are
attenuated
t


Rhodamine 6G
dye jet
R = 10 cm
R = 5 cm
argon laser pump beam
R = 5 cm
internal dye laser beam
R = ∞
DODCI
saturable
absorber
R = 5 cm
output



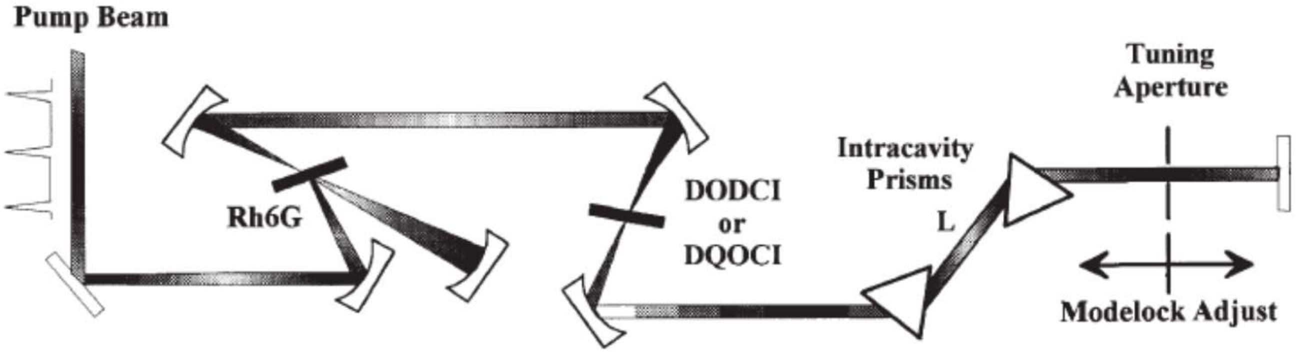
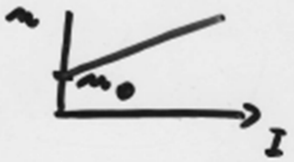


Fig. 3.21. Cavity design of hybrid mode-locked laser with inserted prisms for group velocity dispersion (GVD) compensation

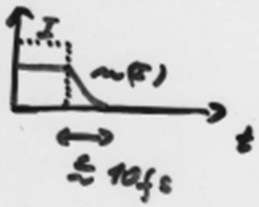
Hybridní ML

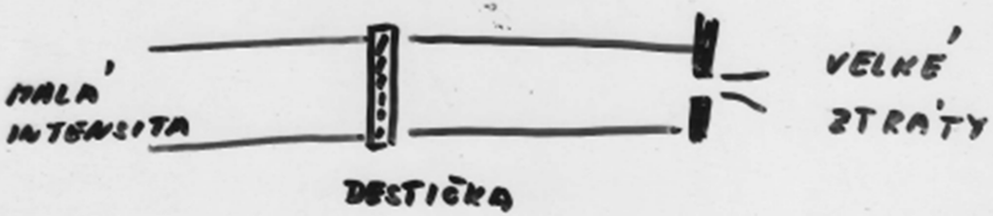
NELINEÁRNÍ OPTIKA.

$$n(I) = n_0 + n_2 I$$



"RYCHLÉ"





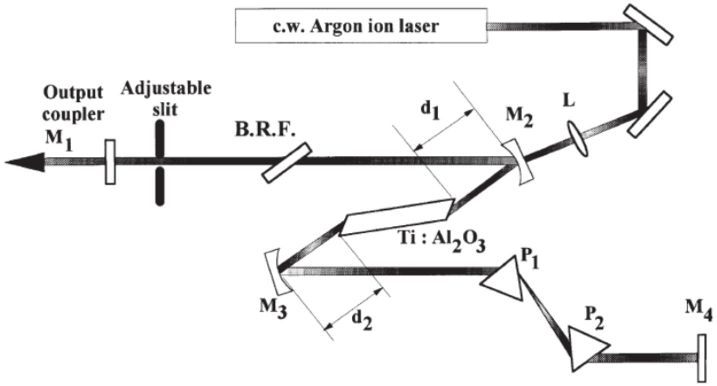


Fig. 3.23. Typical cavity design of a self-mode-locked Ti:sapphire laser using the KLM (Kerr lens mode-locking) process (see text)

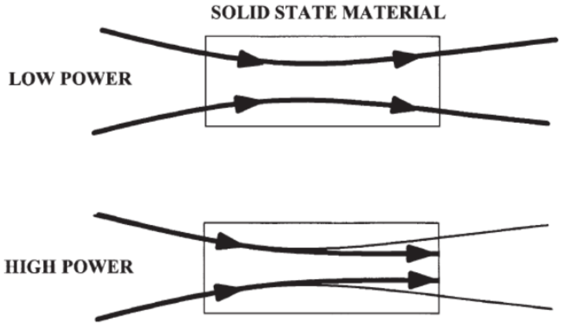


Fig. 3.24. Illustration of the self-focusing effect by the optical Kerr effect on the beam waist of a laser beam at high and low intensity

Kerr ML

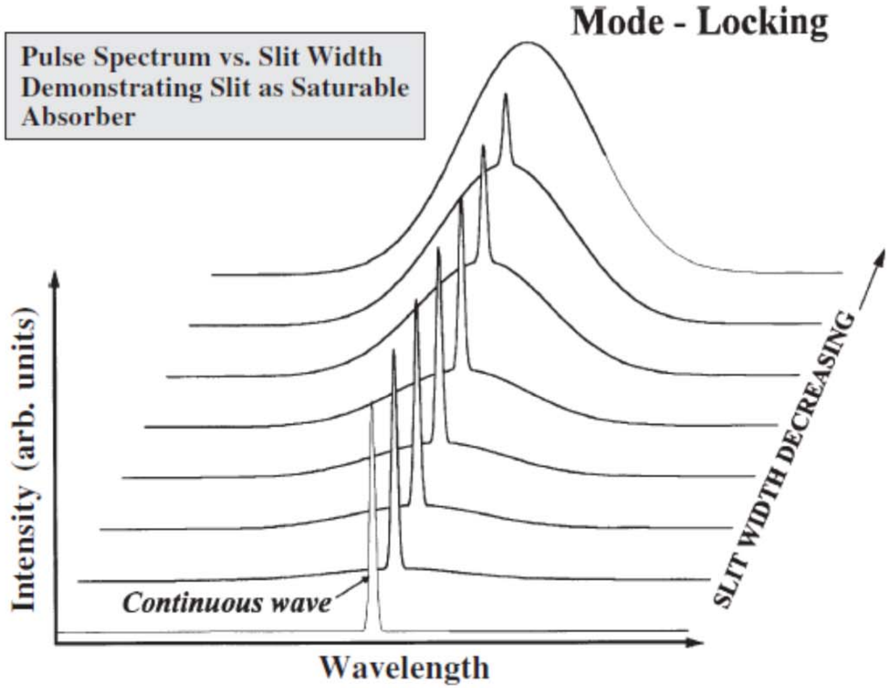


Fig. 3.25. Spectral distribution of laser output for different widths of the slit inserted in the cavity, which controls the mode-locking by the optical Kerr effect

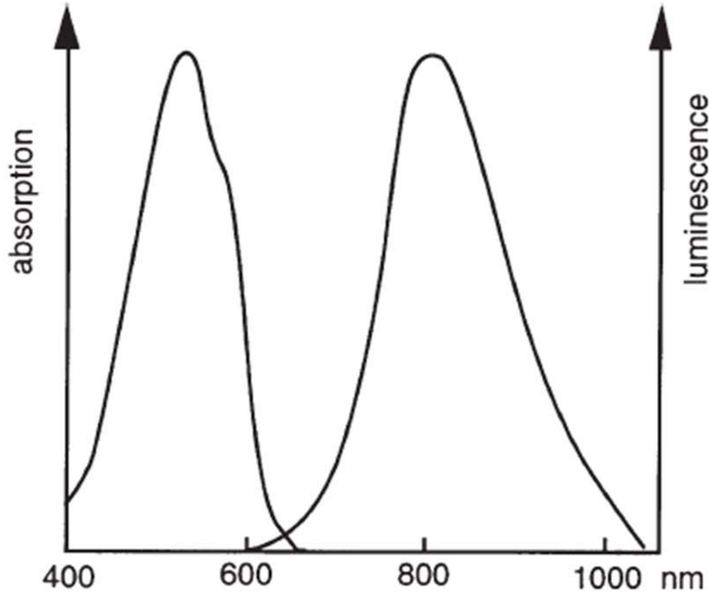


Fig. 4.15. Normalized absorption and emission spectra of Ti^{3+} ions embedded as impurities in a sapphire matrix ($Ti:Al_2O_3$)

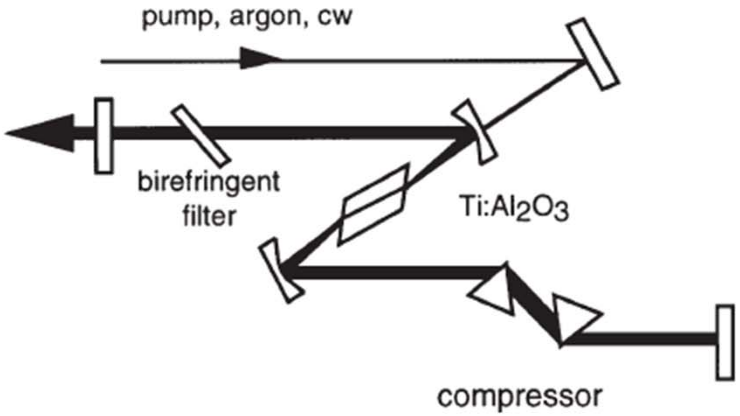


Fig. 4.16. Simplified sketch of a Ti:sapphire laser

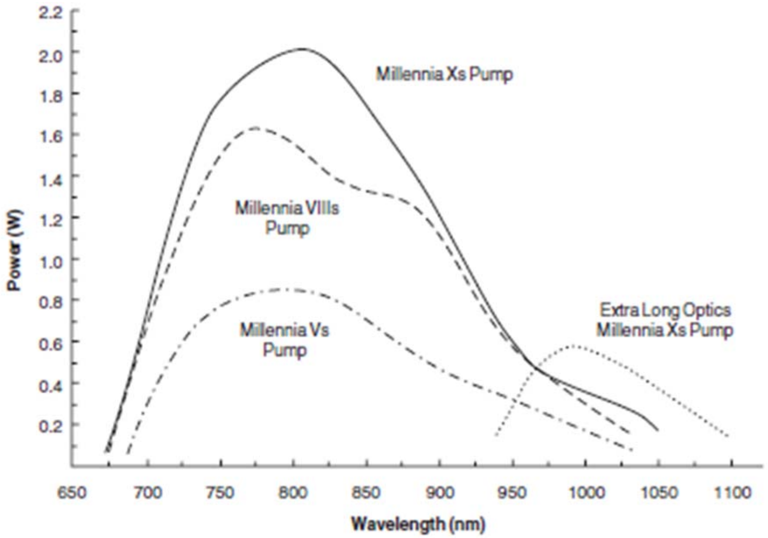


Figure 3-5: ***Tsunami*** **femtosecond tuning curves for broadband optics when pumped by the various** ***Millennia*** **diode-pumped cw lasers shown.**

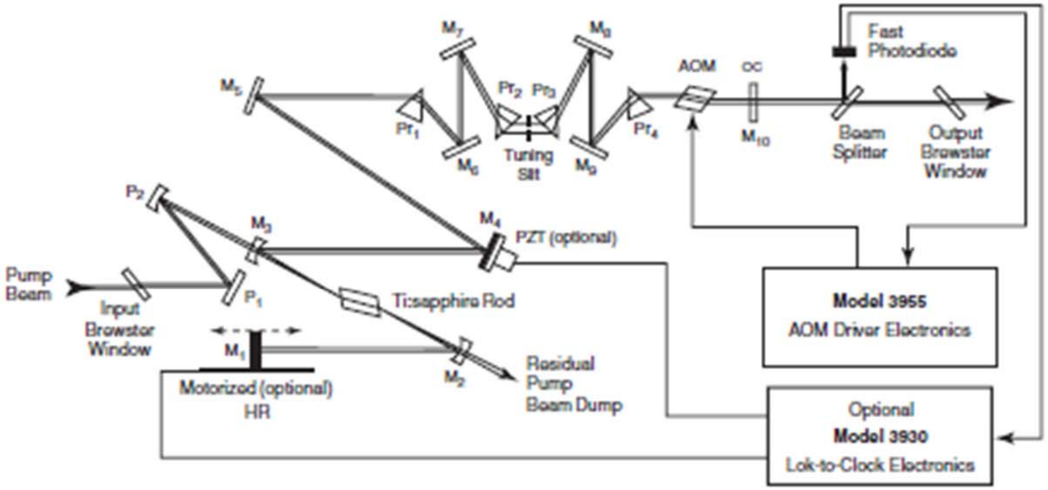
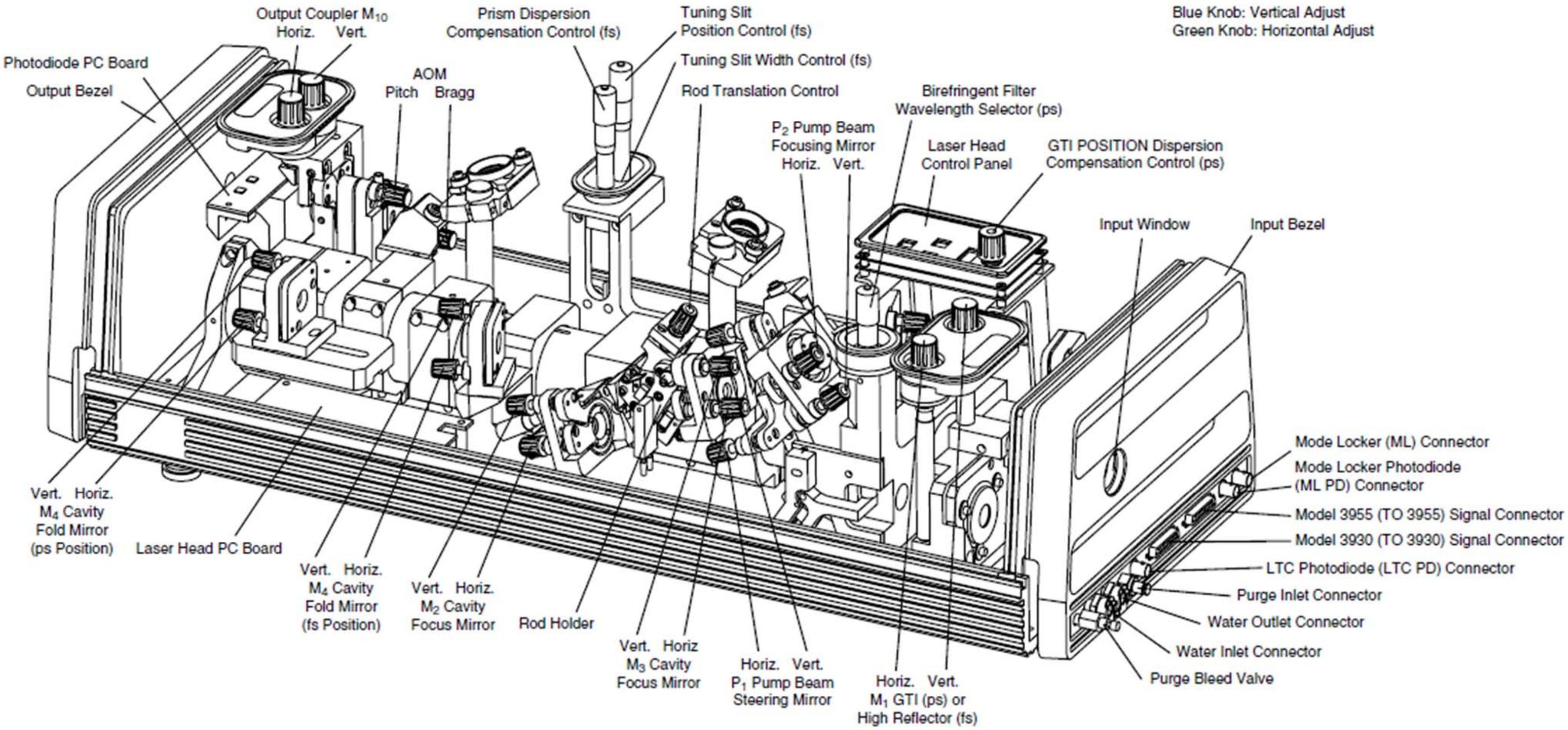
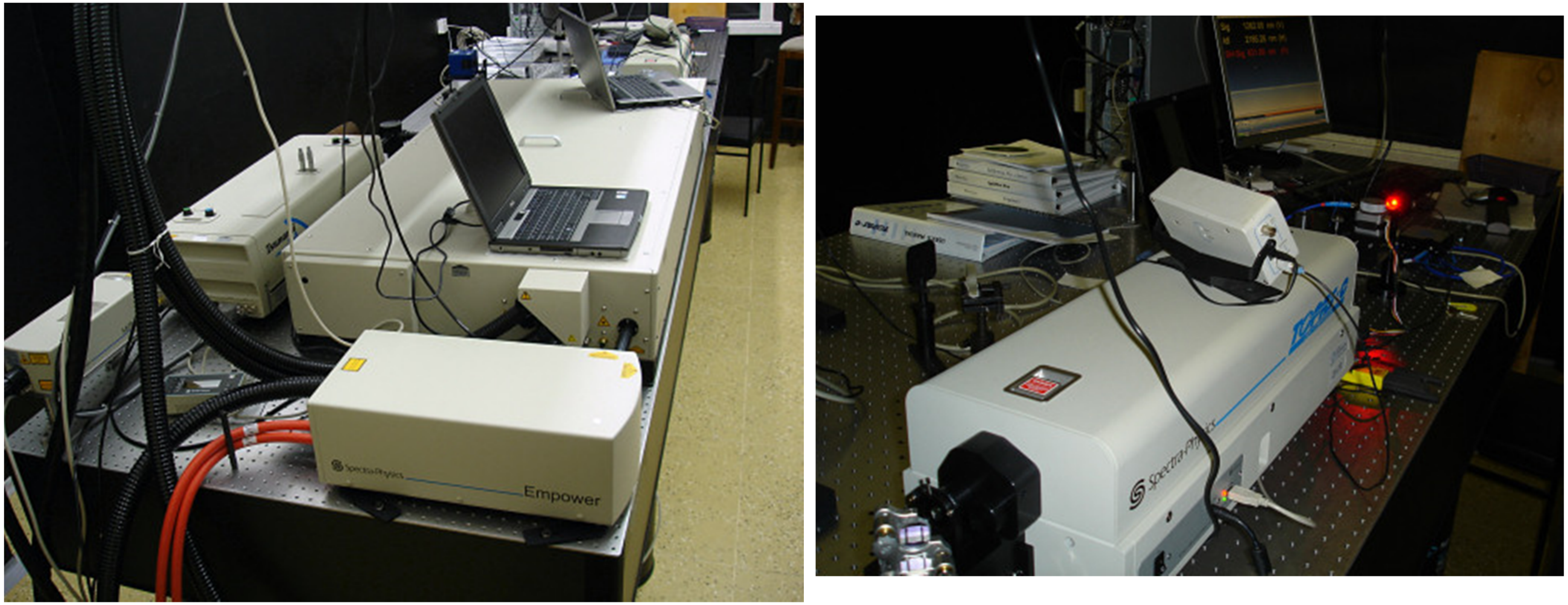


Figure 3-3: Beam Path for *Tsunami Models 3960* and *3941* Femtosecond Configurations


Output Coupler M_{10}
Horiz. Vert.
Prism Dispersion
Compensation Control (fs)
Tuning Slit
Position Control (fs)
Tuning Slit Width Control (fs)
Blue Knob: Vertical Adjust
Green Knob: Horizontal Adjust
Photodiode PC Board
Output Bezel
AOM
Pitch Bragg
Rod Translation Control
Birefringent Filter
Wavelength Selector (ps)
P_2 Pump Beam
Focusing Mirror
Horiz. Vert.
Laser Head
Control Panel
GTI POSITION Dispersion
Compensation Control (ps)
Input Window
Input Bezel
Mode Locker (ML) Connector
Mode Locker Photodiode
(ML PD) Connector
Model 3955 (TO 3955) Signal Connector
Model 3930 (TO 3930) Signal Connector
LTC Photodiode (LTC PD) Connector
Purge Inlet Connector
Water Outlet Connector
Water Inlet Connector
Purge Bleed Valve
Vert. Horiz.
M_4 Cavity
Fold Mirror
(ps Position)
Laser Head PC Board
Vert. Horiz.
M_4 Cavity
Fold Mirror
(fs Position)
Vert. Horiz.
M_2 Cavity
Focus Mirror
Rod Holder
Vert. Horiz
M_3 Cavity
Focus Mirror
Horiz. Vert.
P_1 Pump Beam
Steering Mirror
Horiz. Vert.
M_1 GTI (ps) or
High Reflector (fs)

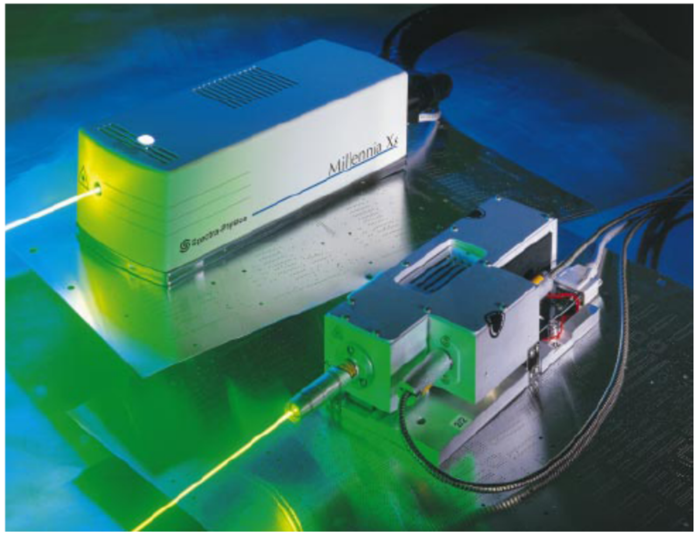


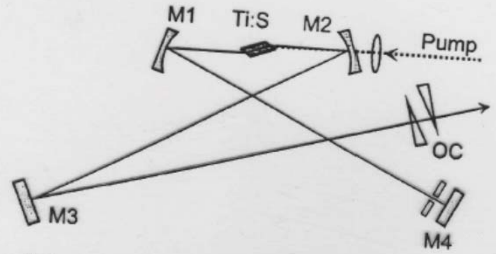
Femtosekundová laboratoř- Ti:safírový laserový systém,
Spectra-Physics, 2007

Čerpací lasery

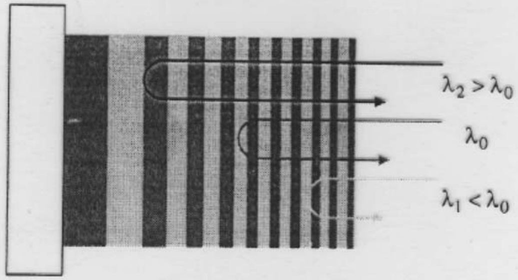
Millenia: čerpací laser, cw, Nd:YVO$_4$, 5 W, SHG LBO 532 nm
(sám čerpán polovodičovými diodami na 809 nm)

Empower: čerpací laser, Q spínaný, Nd:YLF , > 20 mJ v pulsu 100 ns,
SHG LBO527 nm
(sám čerpán polovodičovými diodami na 809 nm)





Schematic of a mirror-dispersion-controlled Ti:sapphire laser made up of chirped mirrors (M1-M4), a broadband output coupler (OC), and a thin, highly doped Ti:sapphire crystal (Ti:S);



Chirped mirrors

High-dispersive mirrors for femtosecond lasers

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[1] *Ludwig-Maximilians-Universitaet Muenchen, Am Coulombwall 1, D-85748 Garching, Germany*
[2] *Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany*
**Corresponding author: volodymyr.pervak@mpq.mpg.de*

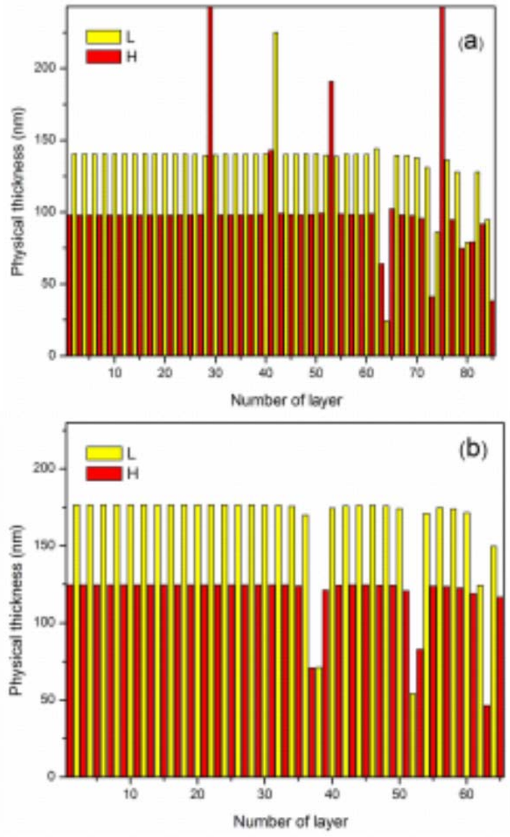


Fig. 1. The refractive index profile of HDMs. (a): HDM for Ti:Sa CPO, (b): for Yb:YAG oscillator.

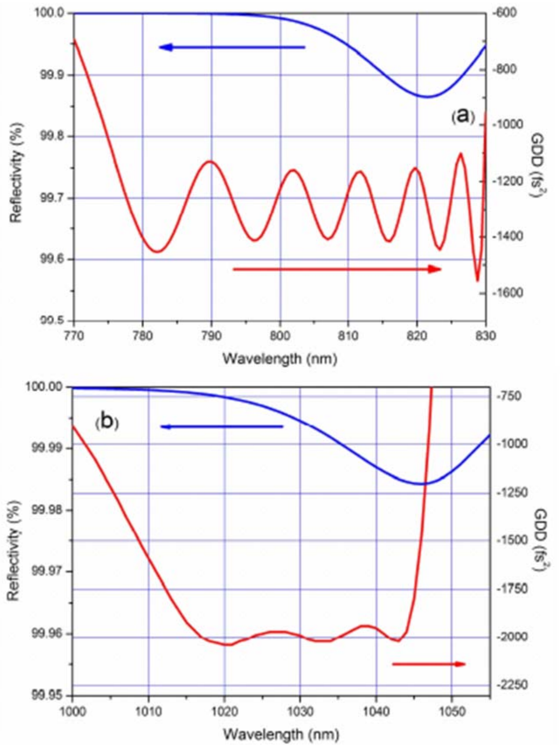


Fig. 2. The calculated GDD and reflectivity of HDMs. (a): HDM for Ti:sapphire CPO, (b): for Yb:YAG oscillator.

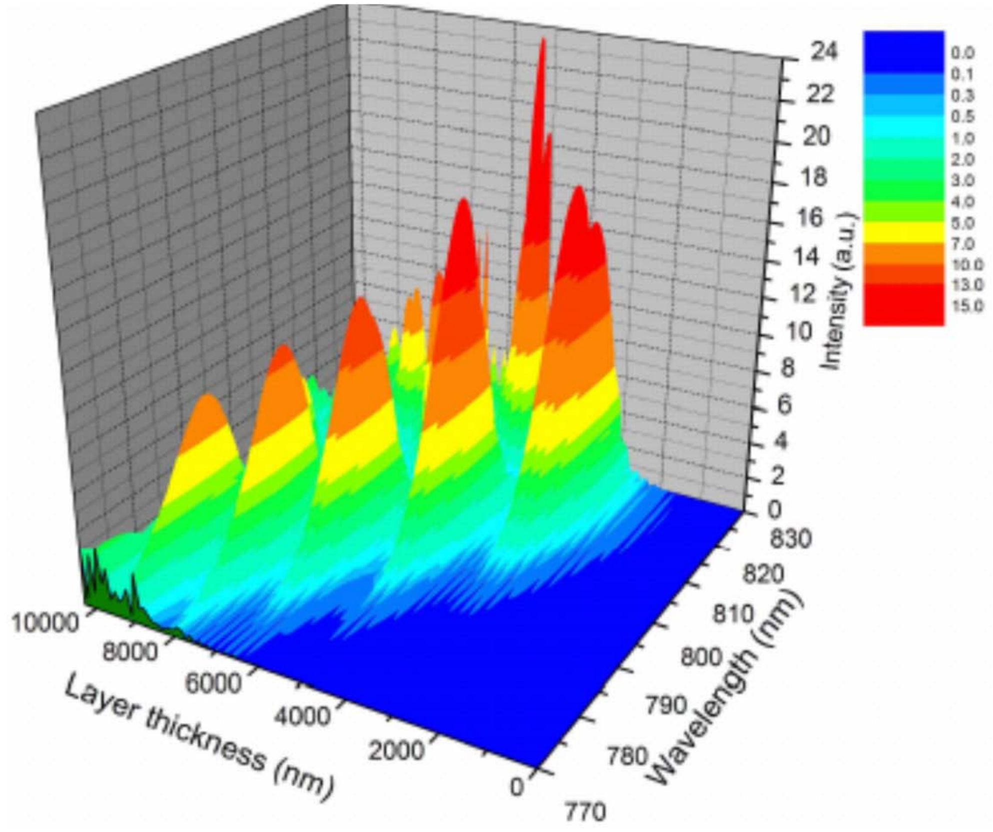


Fig. 6. The penetration depth of spectral components into the HDM structure shown in Fig.1a. Light enters the structure from the left side.

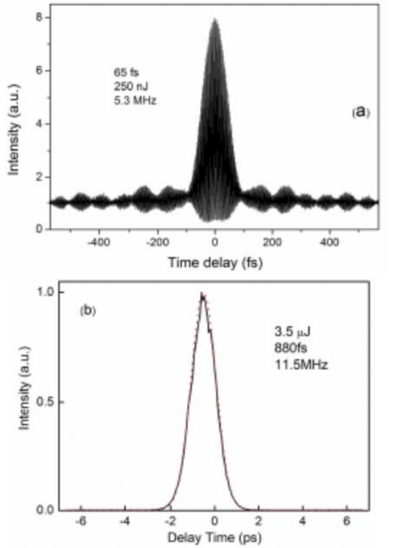
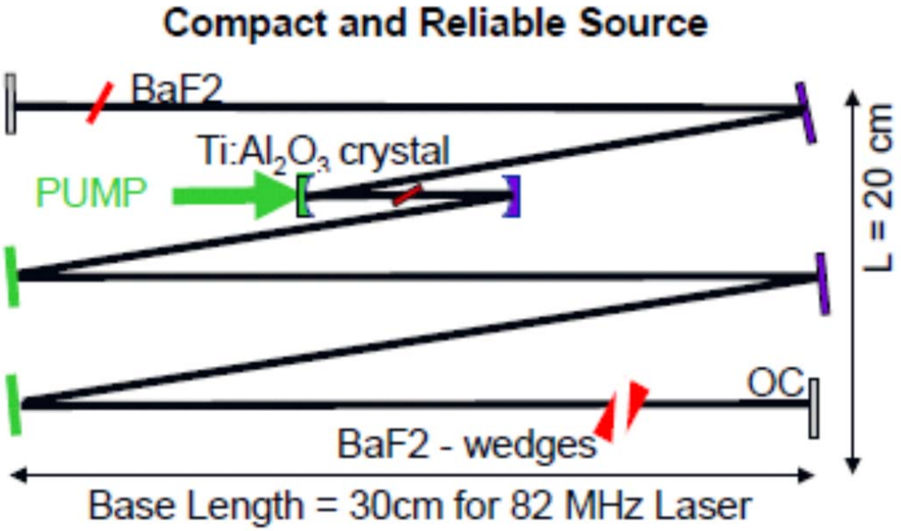
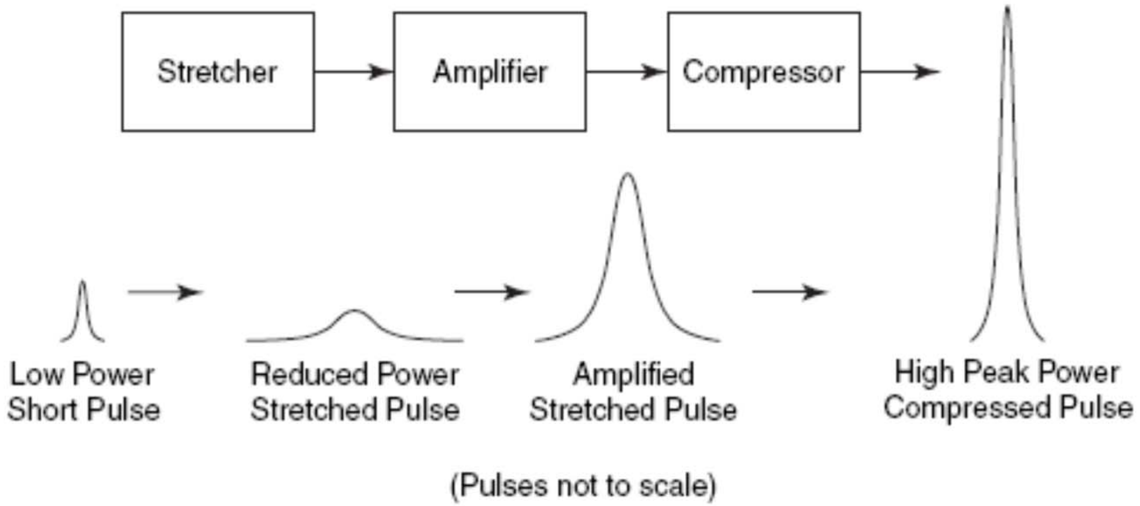


Fig. 7. (a): Interferometric autocorrelation trace of 0.25-μJ pulses delivered by a Ti:Sa CPO and compressed via 20 bounces off the 800-nm HDMs presented above. (b): Intensity autocorrelation trace of 3.5-μJ pulses produced by an Yb:YAG disk oscillator.



5 fs laser design



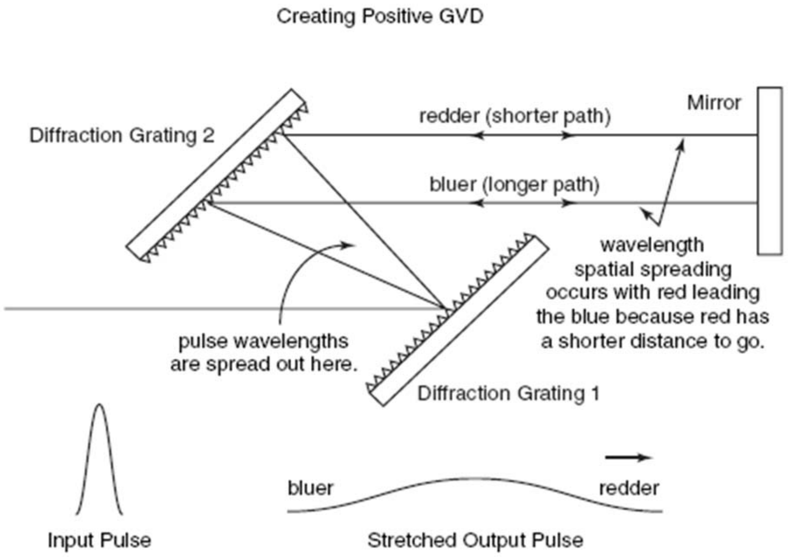
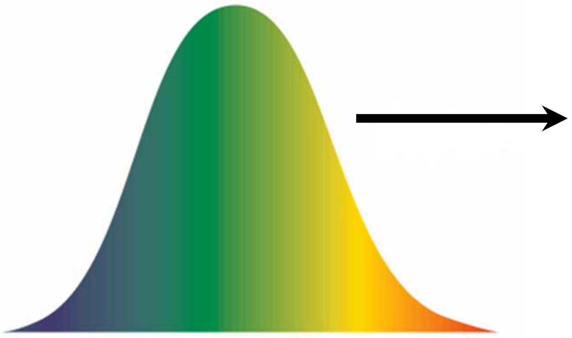
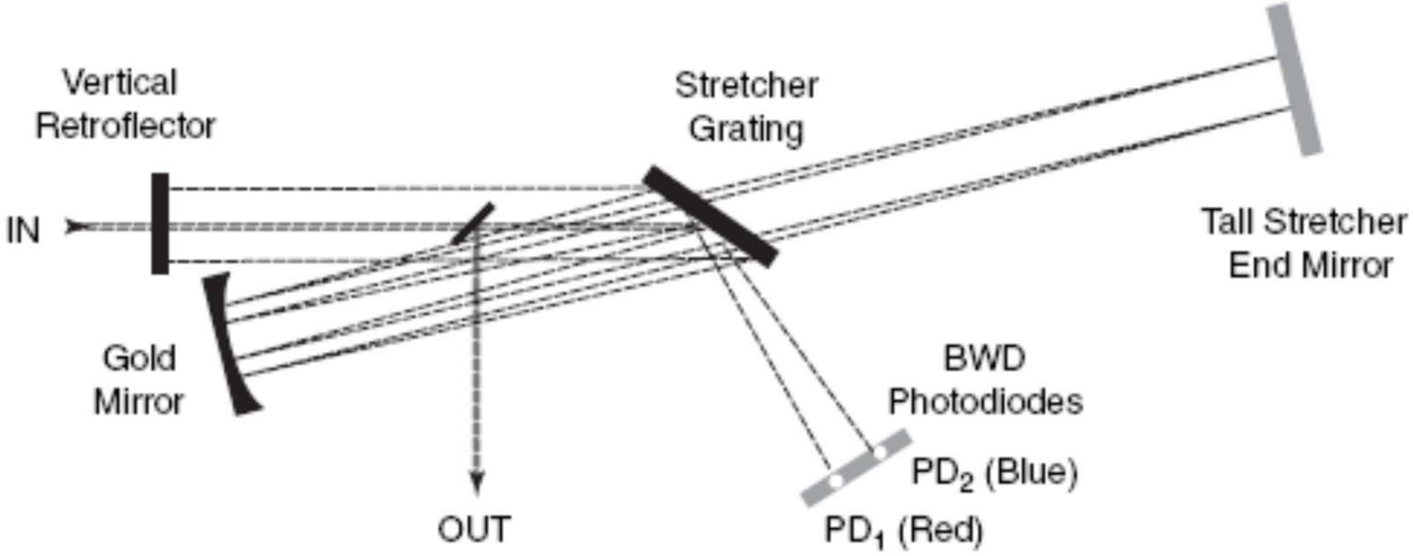


Figure 3-4: Principle of pulse stretching using positive GVD




Vertical Retroflector
Stretcher Grating
Tall Stretcher End Mirror
IN
Gold Mirror
BWD Photodiodes
PD$_2$ (Blue)
PD$_1$ (Red)
OUT