Setup and characterization of a Grism-compressor for a dispersion control of ultra short pulses

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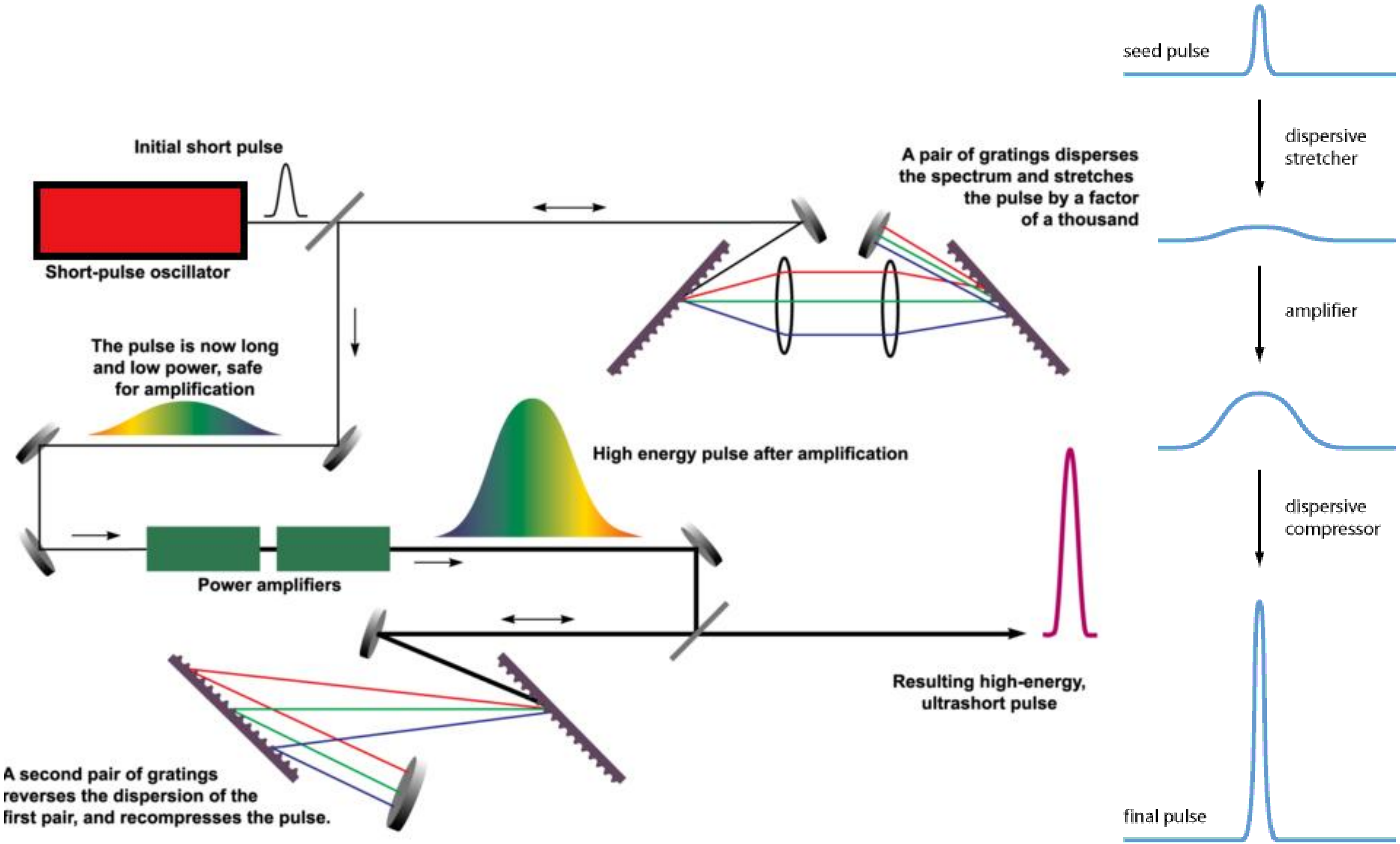
Short outline

- Chirped Pulse Amplification systems
- Penelope laser system
- Grism compressor
- Theoretical model
- Experiment

Chirped Pulse Amplification



http://en.wikipedia.org/wiki/File:Chirped_pulse_amplification

http://www.rp-photonics.com/chirped_pulse_amplification.html

Dispersion

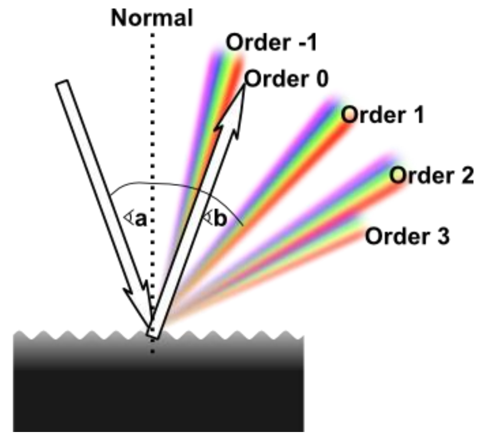
Dispersion is the dependence of phase velocity on the optical frequency or wavelength.

We distinguish **material** and **angular** dispersion.

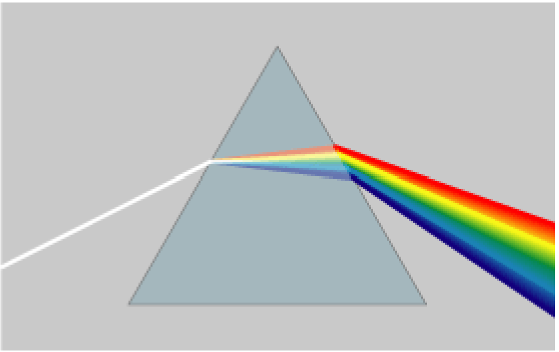
Grating equation:

$$d(sina \pm sinb) = m\lambda$$

where: d – distance between grooves
a – angle of incidence
b – angle of diffraction
m – order of diffraction
λ - wavelength

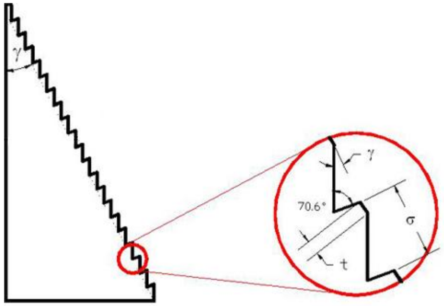


Dispersion on a grating [2].



Dispersion in a prism [3].

Dispersion in fiber or bulk [1].



Taken form:
[1] http://www.thefoa.org/tech/ref/testing/test/CD_PMD.html
[2]http://www.tau.ac.il/~phchlab/experiments_new/SemB01_Hydrogen/02TheoreticalBackground.html
[3] http://en.wikipedia.org/wiki/Dispersion_%28optics

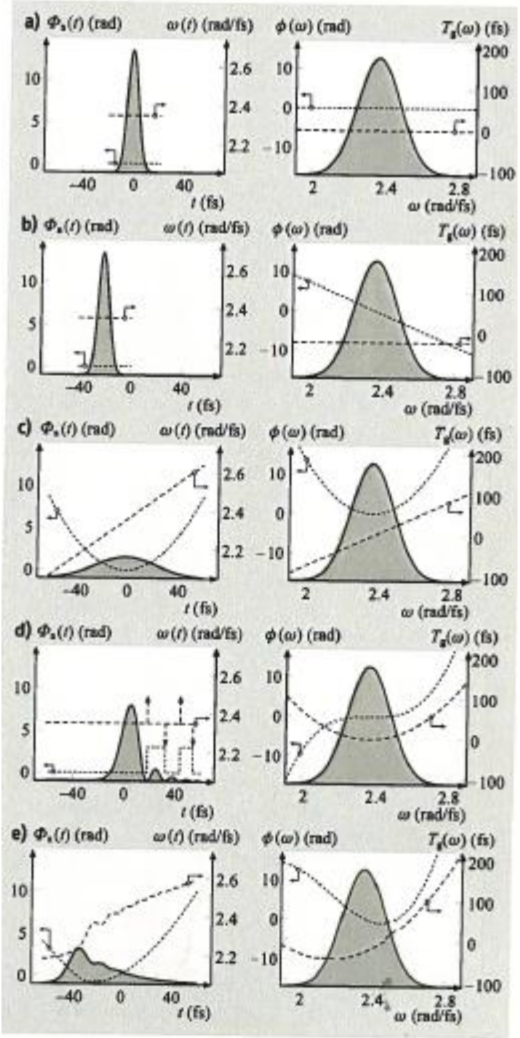
Dispersion

Group Delay Dispersion of an optical element is the derivative of the group delay with respect to the angular frequency, or the second derivative of the change in spectral phase. **It gives the information how much the pulse is compressed (if negative) or stretched (if positive).**

Third-Order Dispersion is the second derivative of the group delay. **Introduces some distortions.**

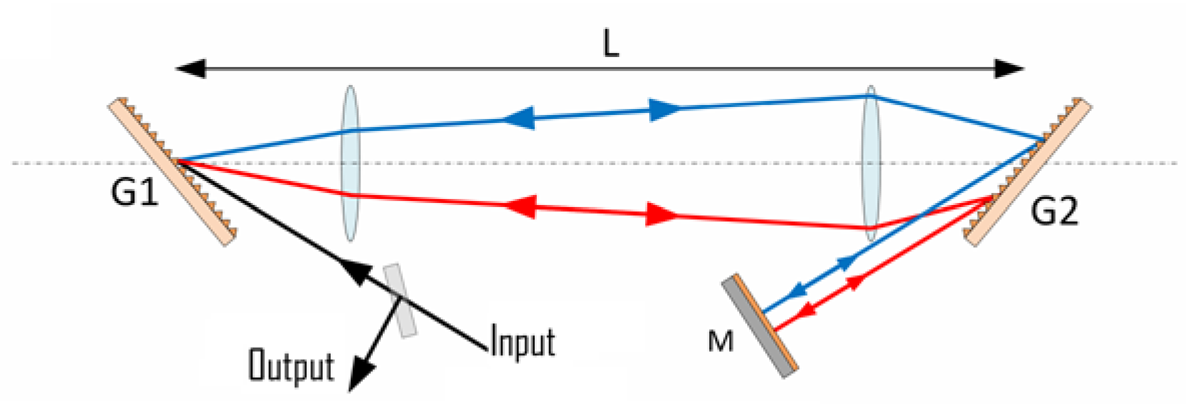
Spectral phase of laser pulse:

$$\phi(\omega) = \phi_0 + \phi_1(\omega - \omega_0) + \phi_2(\omega - \omega_0)^2 + \phi_3(\omega - \omega_0)^3 + \ldots,$$

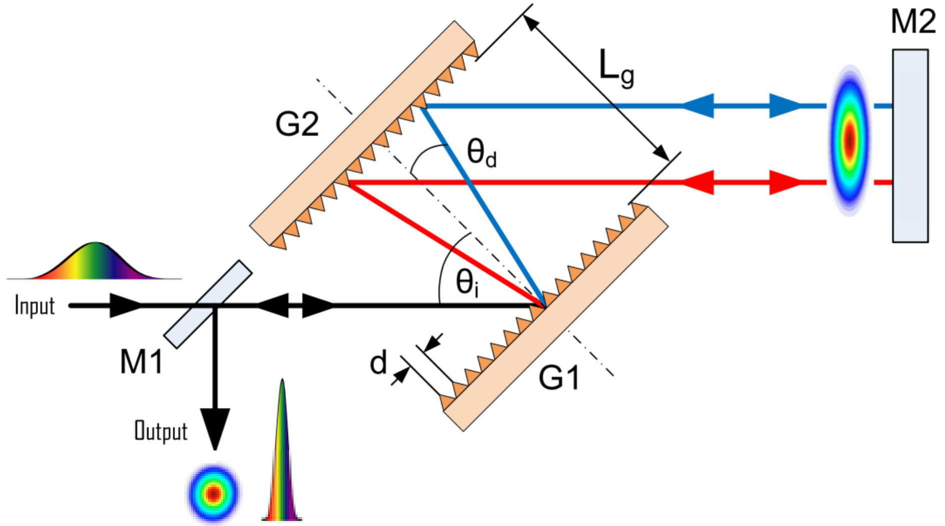


Source: RP Photonics Encyclopedia

Stretcher and compressor design



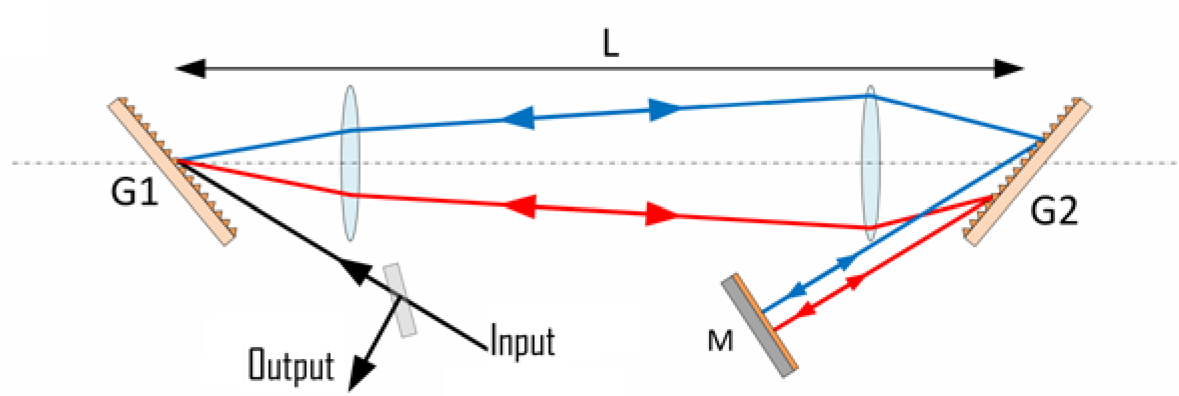
Martinez type stretcher
Gratings are so arranged that **'red'** spectral components has shorter optical path and come out first (before 'blue' spectral components) – dispersion is positive [1].



Treacy type compressor
Gratings are so arranged that **'blue'** spectral components has shorter optical path and come out first (before 'red' spectral components) – dispersion is negative [1].

Taken form:
[1] G. Sobon, "Swiatlowodowe uklady typu MOPA do generacji i wzmacniania ultrakrotkich impulsow laserowych w III oknie telekomunikacyjnym", doctoral dissertation, Wroclaw (2013).

Stretcher and compressor design



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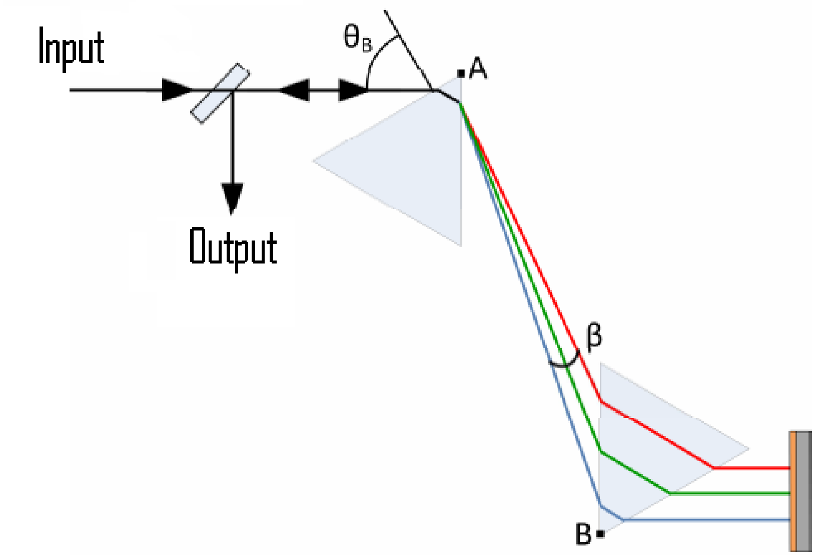

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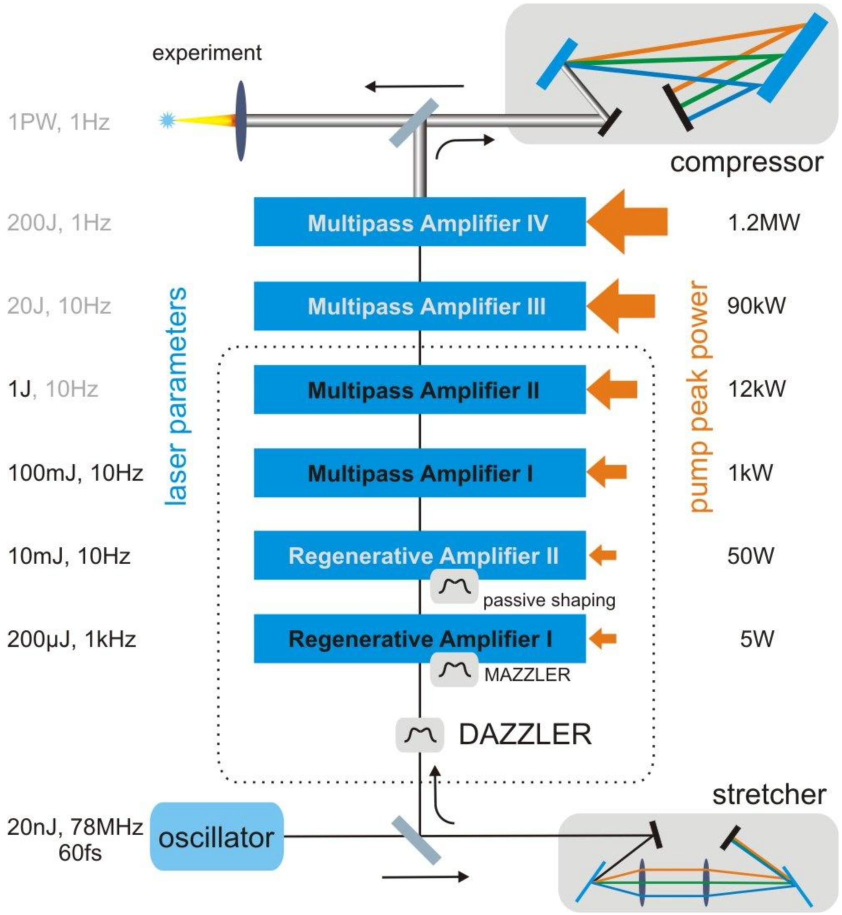
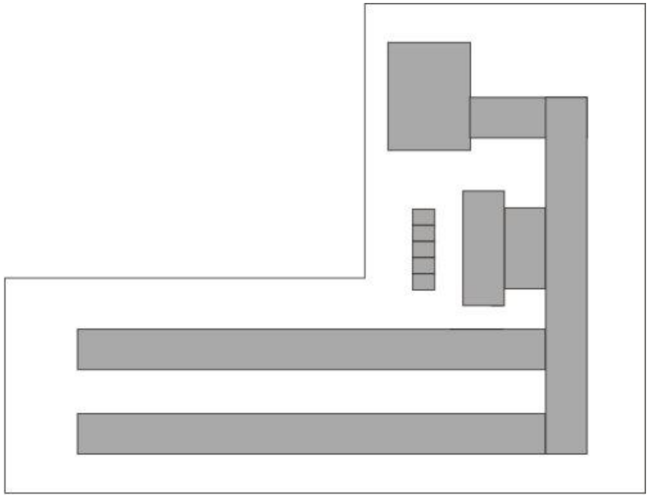
PENELOPE

Petawatt, Energy-Efficient Laser for Optical Plasma Experiments



Laboratory infrastructure

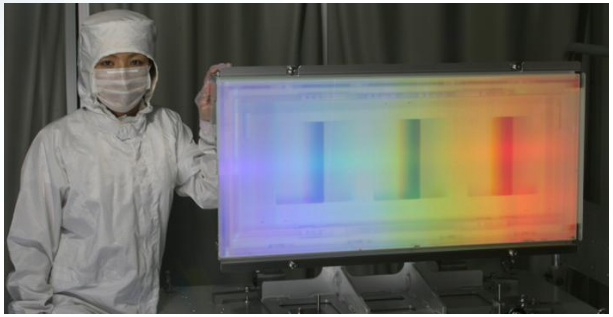


Lab space:
340m^2

Tables:
90m^2

Laboratory infrastructure

Compressor vacuum chamber.



dielectric gratings

940 420 mm^2

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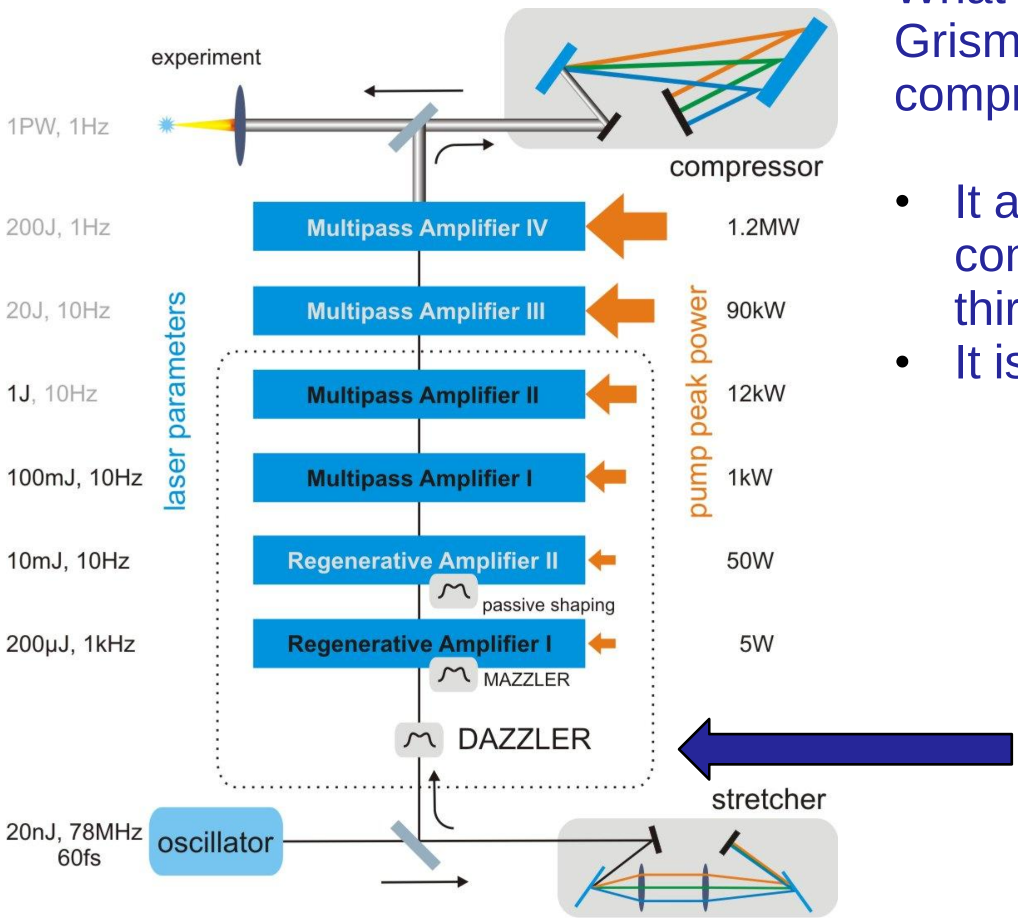
Grism compressor for dispersion control

Additional compressor introduced to the Penelope system allows to control the dispersion without necessity to change the stretcher or end compressor settings.



Grism compressor

What are the benefits of using Grism over traditional compressor?

- It allows for simultaneous compensation of second- and third order dispersion.
- It is very flexible.

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Theoretical model

Appl. Phys. B (2012) 109:121–125
DOI 10.1007/s00340-012-5126-2

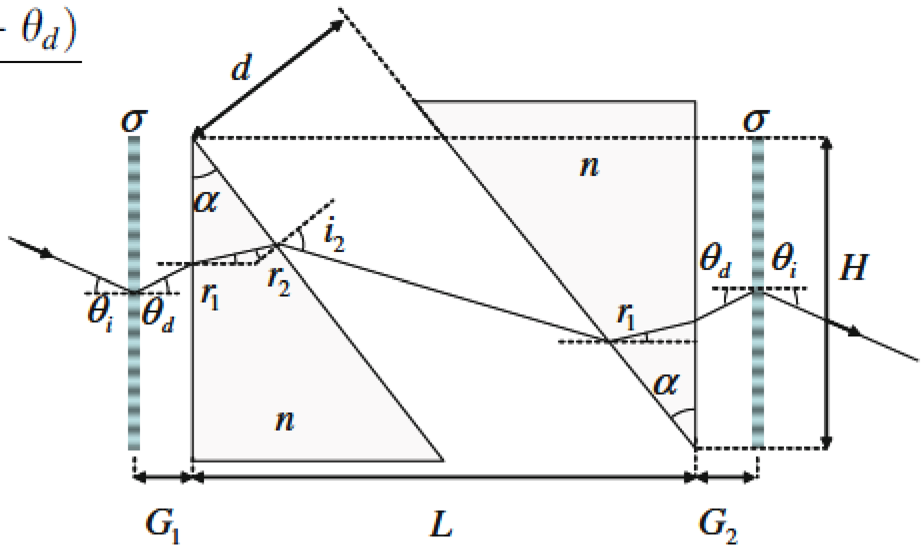
Applied Physics B
Lasers and Optics

Transmission Bragg-grating grisms for pulse compression

Nicolas Forget · Vincent Crozatier · Pierre Tournois

Analytical expression for group delay:

$$c.\tau_p = \frac{d}{\cos(i_2)} + \frac{L}{\cos(r_1)}\left[N - \sin(\theta_i)\frac{\cos(r_2)}{\sin(\alpha)}\right] \times \left[1 - \frac{d}{L}\frac{\cos(\alpha + i_2)}{cos(i_2)}\right] + G\frac{1-\cos(\theta_i - \theta_d)}{\cos(\theta_d)} \quad (1)$$



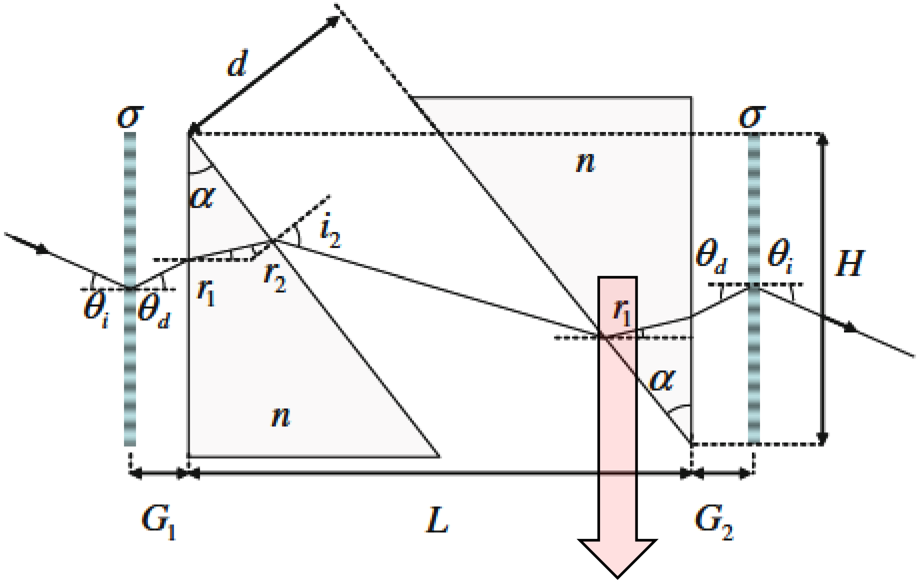
The first derivative of equation (1) is Group Delay Dispersion (GDD).

The second derivative of this equation is Third Order Dispersion (TOD).

Theoretical model – analytical (Mathematica)

Calculation results

	H = 25 mm		H = 28 mm		H = 30 mm	
	From paper	**My results**	**From paper**	**My results**	**From paper**	**My results**
GDD	**-0.164 ps^2**	**-0.168 ps^2**	**-0.13 ps^2**	**-0.14 ps^2**	**-0.10 ps^2**	**-0.12 ps^2**
TOD	$-0.91 \cdot 10^5$ fs^3	$-0.61 \cdot 10^5$ fs^3	$0.091 \cdot 10^5$ fs^3	$0.090 \cdot 10^5$ fs^3	$0.53 \cdot 10^5$ fs^3	$0.56 \cdot 10^5$ fs^3
$TOD/_{GDD}$	0.555 fs	0.362 fs	-0.070 fs	-0.064fs	-0.53 fs	-0.46fs



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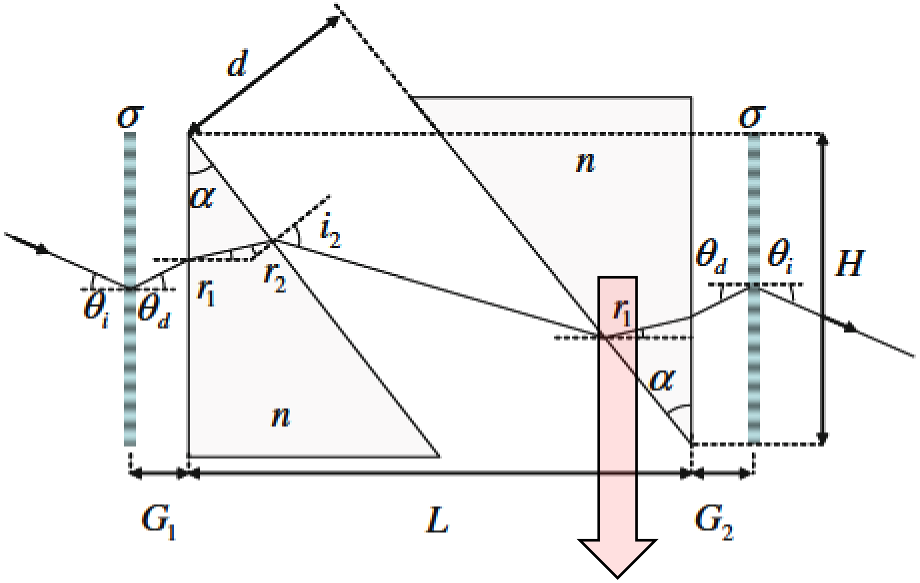
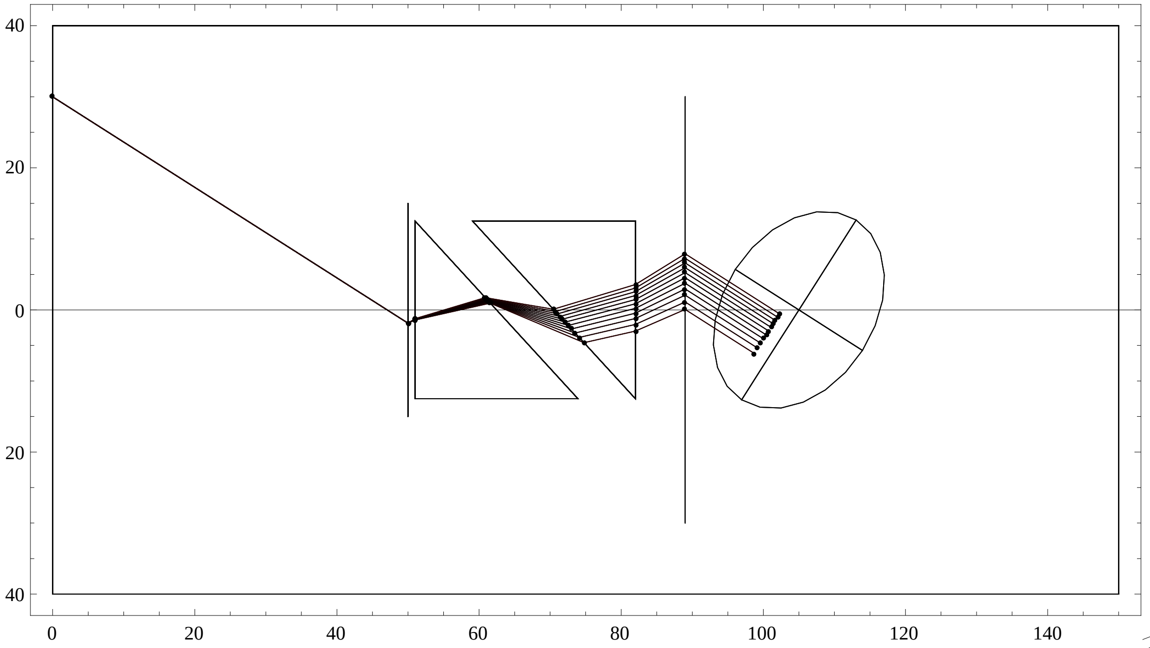
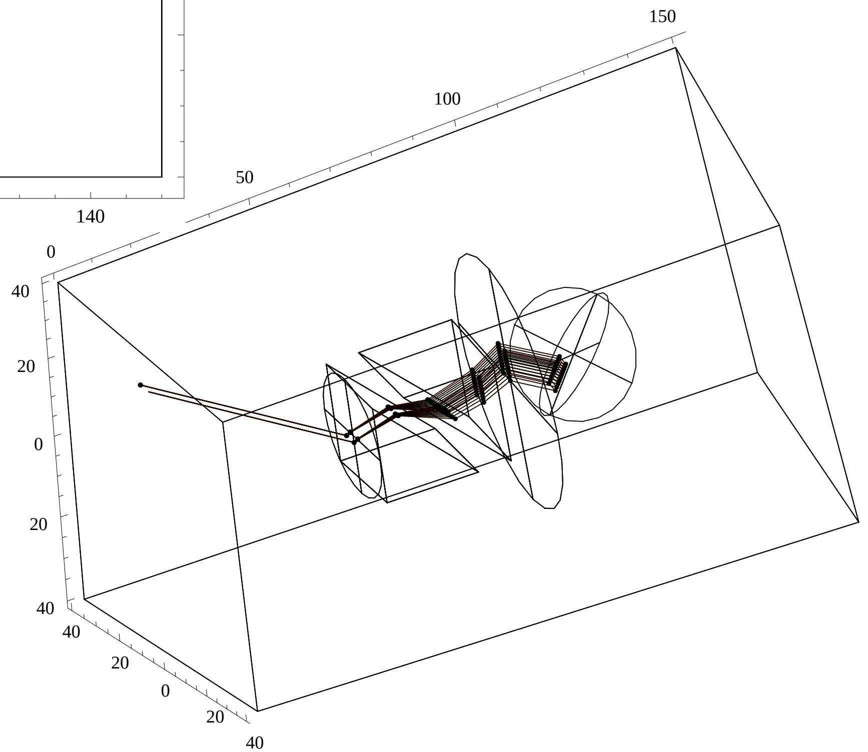


Theoretical model – ray tracing (Optica)





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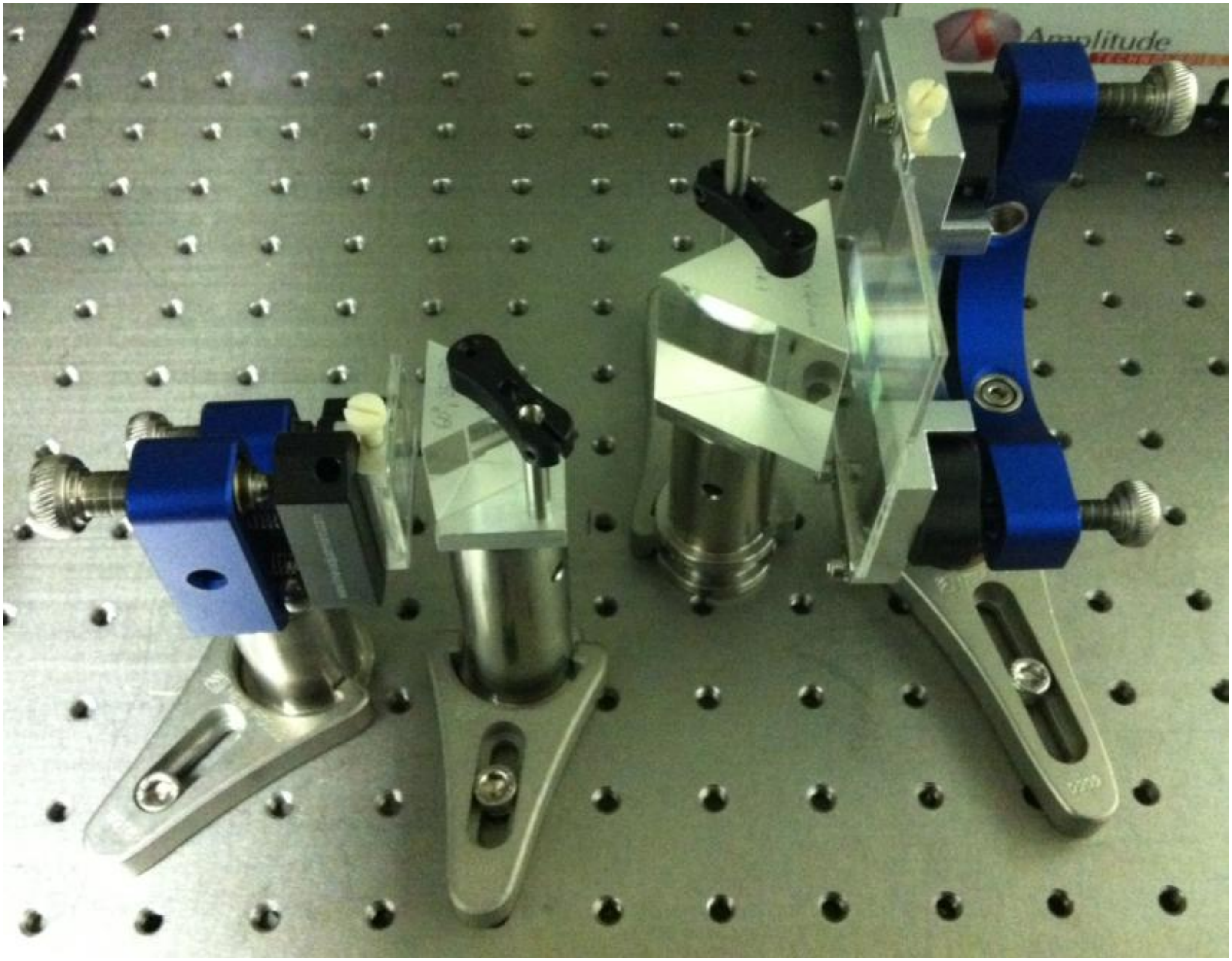

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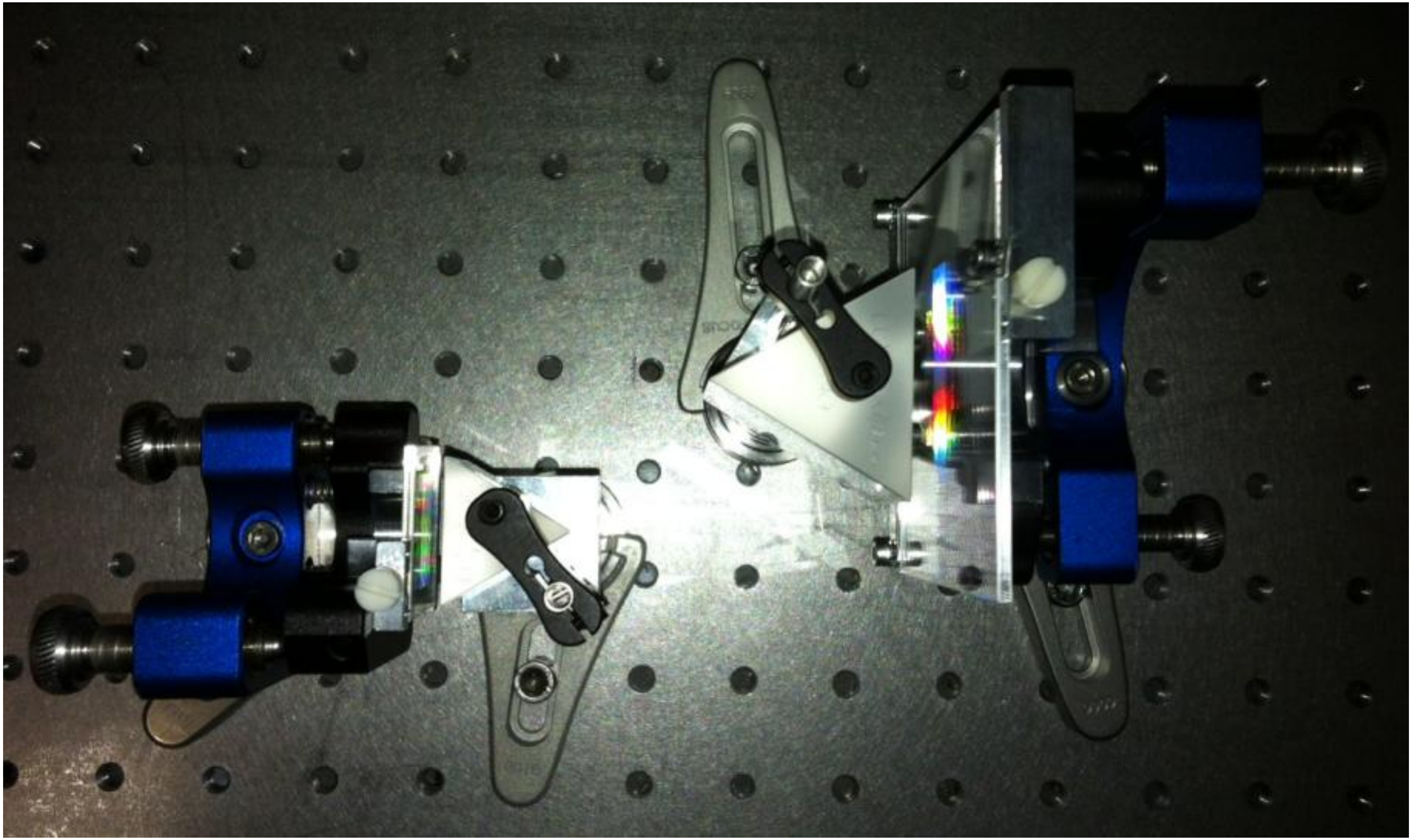

Thank you!