Scheme ASADOG for stretching or compressing short optical pulses

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Overview of the talk

1. Stretching – Compression Schemes: Motivation

2. VBG: Volume Bragg Gratings in Glass

3. **ASADOG** Scheme:

   Achromatic **A**ngular **S**elective **D**iffraction **O**ptical **G**rating

4. ASADOG as
   Stretcher – Compressor with wide spectral range.

5. Modeling of the use of the same Reflection VBG
   with chirp as Stretcher and Compressor.

6. Conclusion

Volume Bragg Gratings (VBG) in special glass.

They were developed by L.B. Glebov et al. at CREOL

and are manufactured by Glebov's Company "OPTIGRATE".

Next two talks will give their overview.

Important:

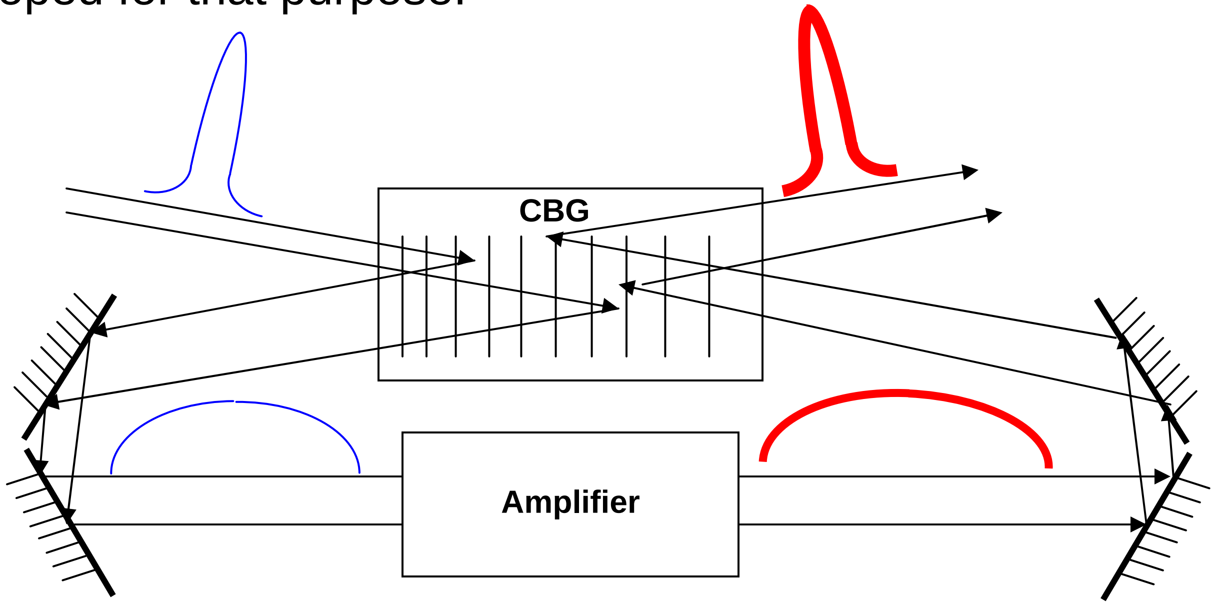
they are very transparent (very low absorption),

therefore they can withstand about 100 Kilo-Watt /cm^2 CW,

and are also tolerant to high peak intensities in ultra-short pulses.

Motivation

Stretching – Amplification – Compression schemes are widely used in generation of ultrashort pulses. The goal is to expose wide spectral band amplifier to low instantaneous intensity, and then compress all the spectral components back into pulse with initial short duration. Various stretcher and compressor schemes are used and studied.
For example, Chirped reflective Volume Bragg Gratings (CBG) were developed for that purpose:

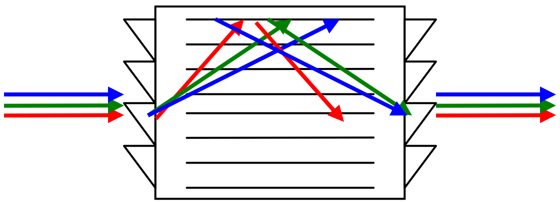


Previous work:

(L. Glebov, V. Smirnov, N. Tabirian and B. Zeldovich, "Implementation of 3D Angular Selective Achromatic Diffraction Optical Grating device", Frontiers in Optics 2003, Talk WW3)

ASADOG Scheme:

Angular **S**elective **A**chromatic **D**iffraction **O**ptical **G**rating



First order of diffraction
by the Surface Optical Grating (SDOG)
of normally incident waves
yields different angles of diffracted waves
of different wavelengths λ:

$$\sin(\theta_{inside}) = \lambda / n\Lambda_{SDOG},$$

where Λ_{SDOG} is the period of Surface DOG.

If the period Λ_{VBG} of the fringes of Volume Bragg Grating is

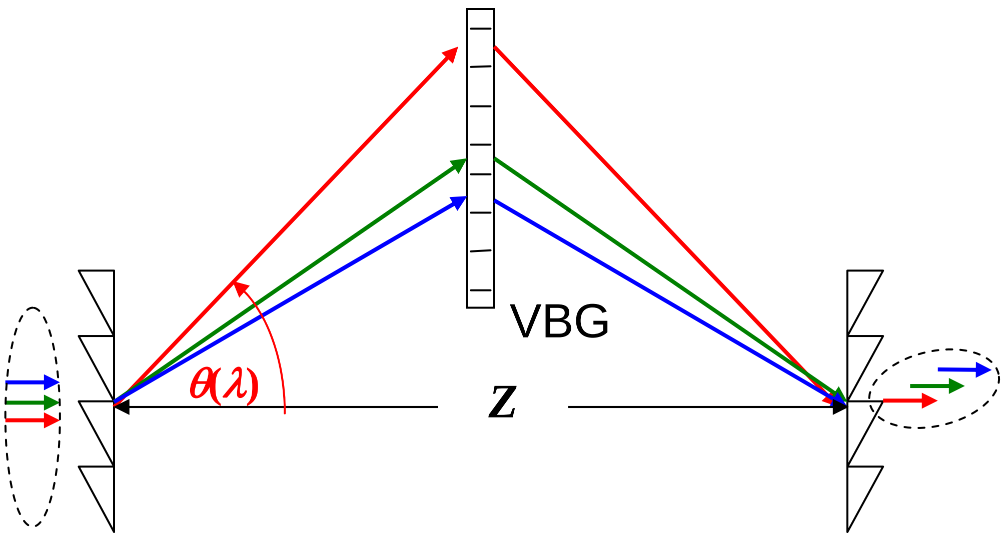
$$\Lambda_{VBG} = (1/2)\ \Lambda_{SDOG},$$

then waves of all colors (i.e. **A**chromatically) satisfy Bragg condition
for VBG diffraction into symmetric set of waves.
Due to high **A**ngular **S**electivity of VBG
this happens only for initial normally incident waves.
Second SDOG may return them to initial direction.
This ASADOG scheme was implemented in **2003** experimentally.

Present work:

Scheme ASADOG for stretching or compressing short optical pulses

Angular **S**elective **A**chromatic **D**iffraction **O**ptical **G**rating(s).



Time delay $T(\lambda) = Z / \{c \cdot \cos[\theta(\lambda)]\}$

Possible advantage: VBG handles easily large change of angle: $2 \cdot \theta(\lambda)$.

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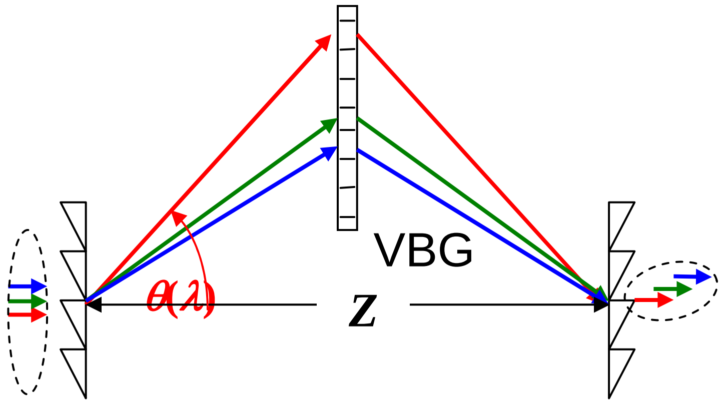

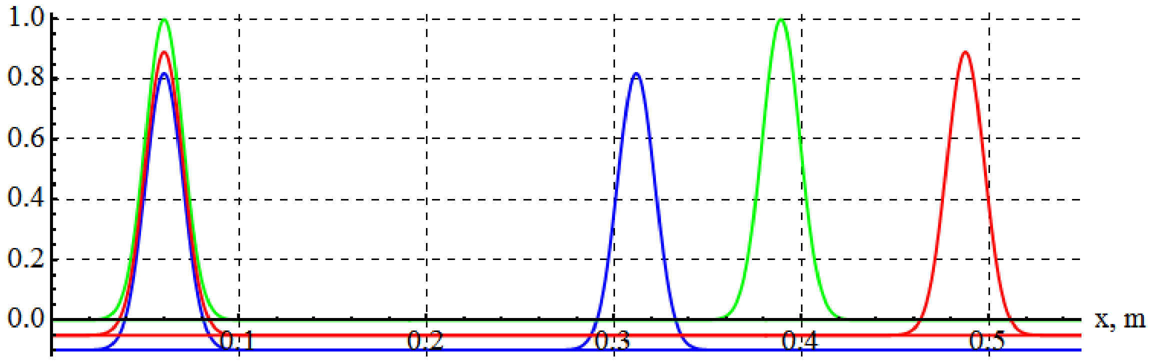

Transverse profiles of intensity of beams:
right, diffracted by sequence of SDOG1 and VBG;
left, finally diffracted by SDOG2 for 3 wavelengths:
650 nm, 550 nm, 450 nm, respectively; Z = 1 meter;
Λ(SDOG)=1 micron for each SDOG.

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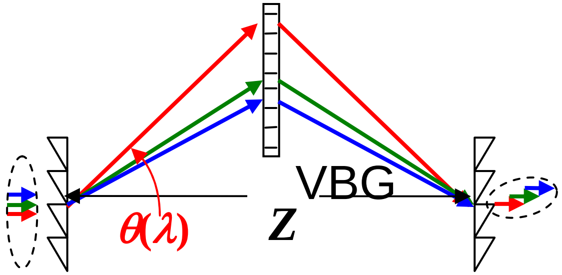
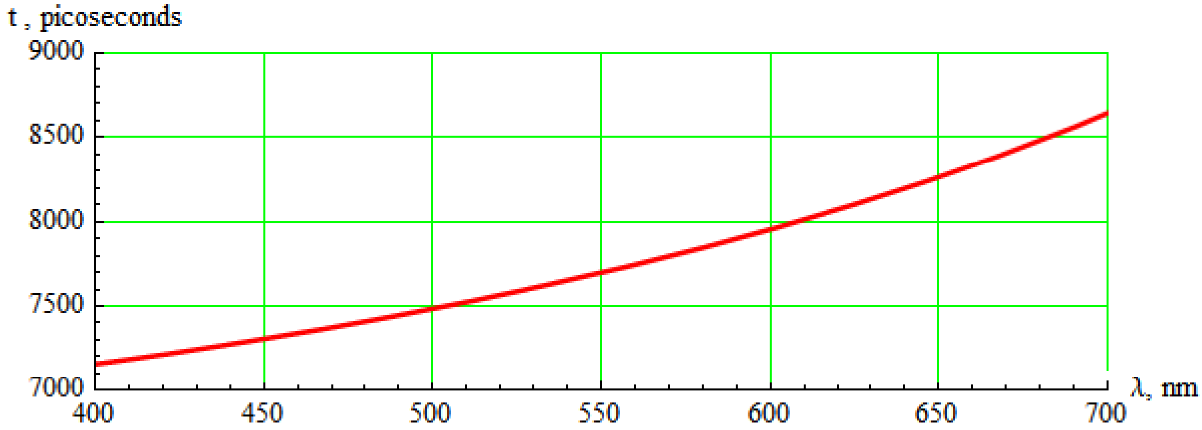
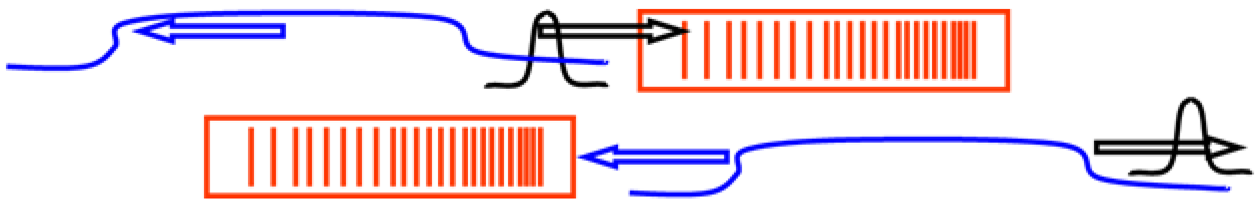


Z = 1 meter for the graph below,
VBG thickness was chosen as 2 mm.



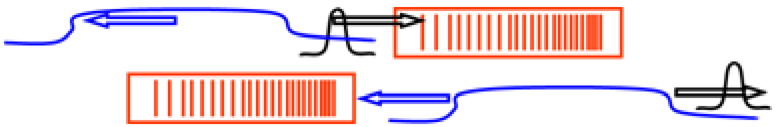
Graph of time delay vs. wavelength; $dT / d\lambda$ = 4.65 ps / nanometer (at 550 nm).
n_1 in $n(x) = n_0 + n_1 \cos(Q \cdot x)$ was chosen n_1 = 130 part per million.
Diffraction efficiencies of this (optimized) strength of the VBG:
η(650 nm) = 0.93, η(550 nm) = 0.995, η(450 nm) =0.93, (s-polarization),
η(650 nm) = 0.99, η(550 nm) = 0.78, η(450 nm) =0.49, (p-polarization),

Modeling of the use of the same Reflection VBG with Chirp (CBG) as Stretcher and Compressor.



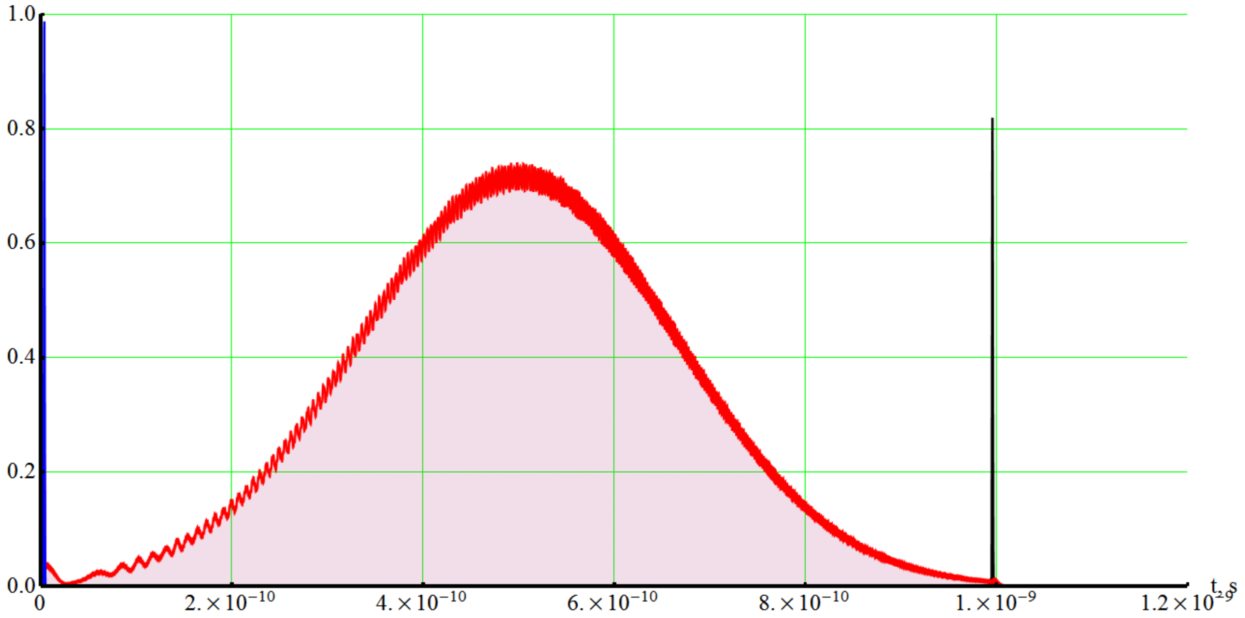
Geometry of stretching (top) and compression (bottom) produced by the same chirped volume Bragg grating.
In modeling no effects of amplifier were considered.

Modeling of the use of the same Reflection VBG with Chirp (CBG) as Stretcher and Compressor.



Particular example: CBG without defects, constant $d\lambda/dz$ = 9.55 pm/cm; Length of CBG L=10 cm, n_1 = 286 ppm, diff. efficiency of single reflection was $\eta \approx 0.99$ within the reflection bandwidth (rather strong CBG), τ_0(HWe^{-2}IM) = 0.75 picoseconds.

Stretched intensity profile is multiplied by factor 320 for better visualization.



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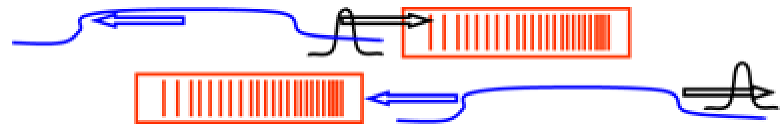
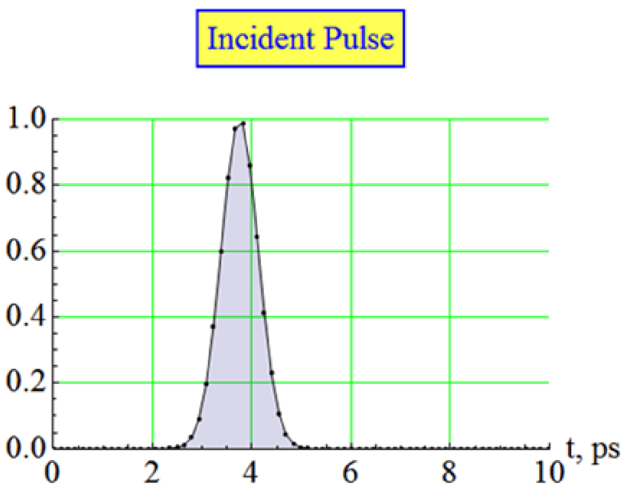
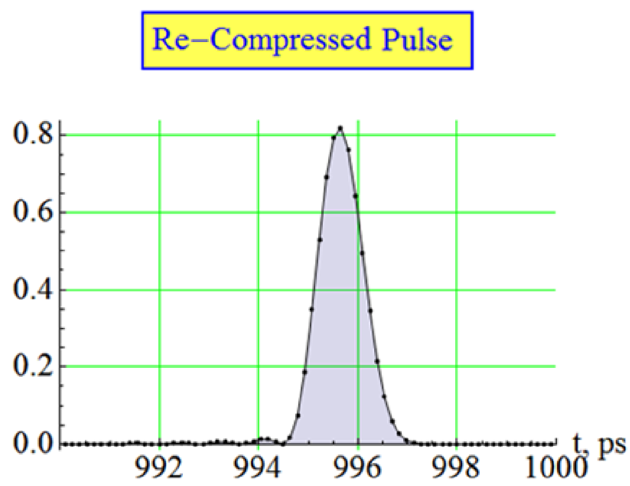
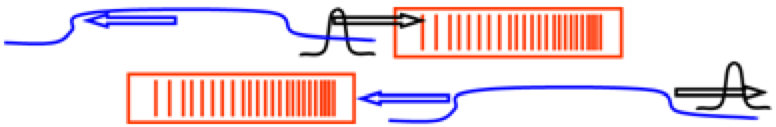


Same particular example: CBG without defects, constant $d\lambda/dz$ = 9.55 pm/cm; Length of CBG L=10 cm, n_1 = 286 ppm, diff. efficiency of single reflection was $\eta \approx 0.99$ within the reflection bandwidth (rather strong CBG), τ_0(HWe^{-2}IM) = 0.75 picoseconds.

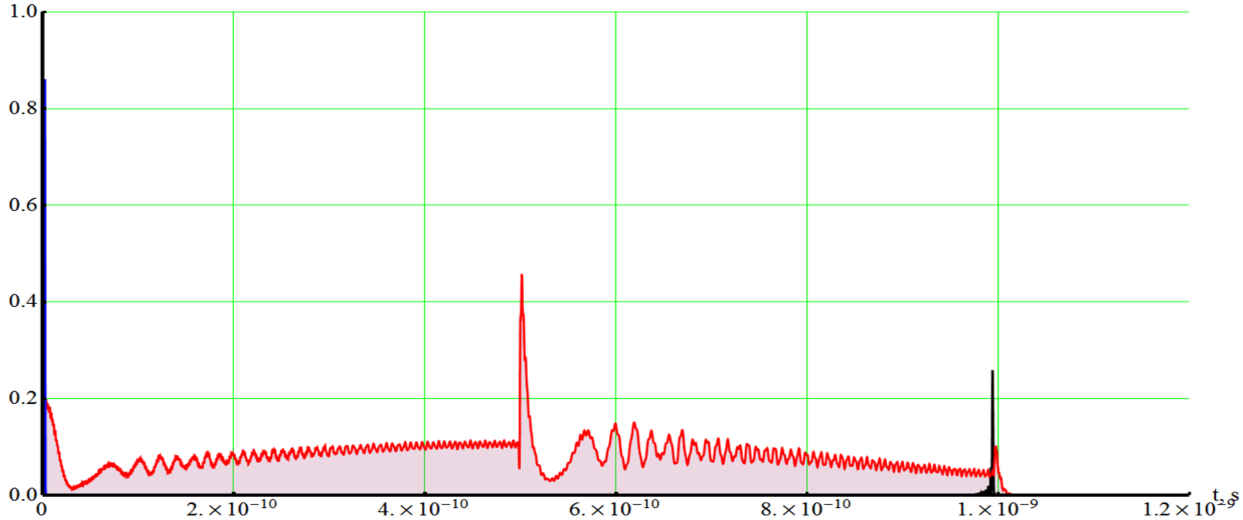




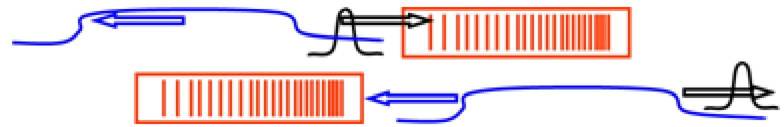
Modeling of the use of the same Reflection VBG with Chirp (CBG) as Stretcher and Compressor.



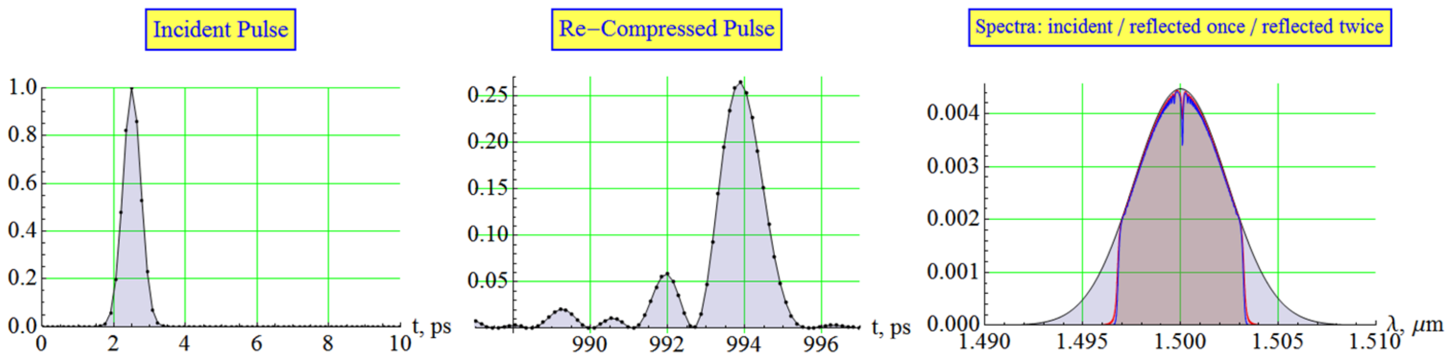
Another example: CBG compound of two pieces L/2 = 5 cm each, with phase shift $\pi/2$ between pieces.
Otherwise, same $d\lambda/dz$ = 9.55 pm/cm; same m, n_1 = 286 ppm,
diff. efficiency of single reflection was $\eta \approx 0.99$ within the reflection bandwidth,
τ_0(HWe^{-2}IM) = 0.5 picoseconds.
Stretched intensity profile is multiplied by factor 160 here (to fit the ugly peak.)



Modeling of the use of the same Reflection VBG with Chirp (CBG) as Stretcher and Compressor.



Example from previous slide: CBG compound of two pieces L/2 = 5 cm each, with phase shift $\pi/2$ between pieces.



η(recompress., energy) = 0.93; η(recompress., peak) = 0.29;
Precursors in re-compressed pulse.
By itself, this re-compression is not so bad,
but the stretched pulse has spike of intensity; bad for amplifier nonlinearities.

Conclusion

1. ASADOG Scheme of pulse stretching or combining is suggested and analyzed.

2. Numerical modeling of Stretching – Compression by Chirped VBG is easily done for multiple particular cases.

3. Too strong a grating is not very good for fidelity of re-compression (results of modeling + analytic approximation.)