Simulation of interaction of the femtosecond laser pulses with chirped mirror

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Chirped Mirrors and femtosecond generation

- Dispersion effect is one of the limiting factor of ultrafast generation
- Chirped mirrors permit to control the net intracavity dispersion
- The goal of design methods is to obtain structure for optimal dispersion compensation
Chirped mirrors and pulse compression

SiO$_2$/TiO$_2$

$n_l = 1.5 \quad n_h = 2.5$
1. Input transform limited pulse

\[ E(t) = E_0 \exp \left( -2 \ln 2 \frac{t^2}{\tau_0^2} \right) \exp \left( i\omega_0 t \right) \]

2. Broadened pulse (chirp) (Sellmeier equation)

\[ \varphi(\omega) = \frac{\omega n(\omega) L_m}{c} \]

3. Chirped mirror reflectivity (Transfer matrix eq)

\[ r_M = \sqrt{R} \exp(i\Phi) \]

4. Compressed pulse after reflection

\[ E_{\text{ref}}(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F_{\text{pas}}(\omega) \exp(i\omega t) \cdot r_M(\omega) d\omega \]
Dispersion compensation

\[ GD(\omega) = \frac{d\varphi(\omega)}{d\omega} \]
Pulse compression in CM with GD oscillations

![Graph showing pulse compression](image)

- Red line: broadened pulse
- Green line: compressed pulse

- Intensity, a.u.
- Time, fs

- N=10
- Values: 18.86, -18.00, 75.74, 133.32
Pulse compression in CM with desired GD
Pulse compression stages

- Compression in CM with GD oscillations
- Compression in CM with desired GD
Chirp compression

- transform-limited pulse
- broadened pulse
- compressed pulse
GD oscillations distort pulse profile

- compressed pulse in CM with GD oscillations
- compressed pulse in CM with desired GD
TOD compensation

Phase shift

\[ \phi(\omega) = \phi(\omega_0) + \]

\[ D_1 \cdot (\omega - \omega_0) + \]

\[ \sum_{n=2}^{\infty} \frac{1}{n!} D_n (\omega - \omega_0)^n \]

\( D_3 = -96 \text{ fs}^3 \)

\( D_2 = -133 \text{ fs}^2 \)

\( D_1 = -13.6 \text{ ps} \)

6.8

7.4

compressed pulse in CM with desired GD

compressed pulse with compensated TOD
Conclusions

The model of interaction of femtosecond laser pulses with chirped mirror is developed.

Developed model allows improving chirped mirror design with purpose of obtaining better reflected pulse quality.

It was revealed the reflected pulse profile drawbacks caused by chirped mirror design imperfection and the way to eliminate it.