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Group delay investigation of *N*-order chirping mirrors

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Abstract. We present the numerical calculation of *N*-order chirping mirrors with chirping both high and low refractive index layers using the transfer matrix method. The group delay and group delay dispersion are investigated for these structures. It is shown that the group delay dispersion is negative and constant at Bragg wavelength for four-order chirping mirrors.

Keywords: chirping mirrors, Bragg grating, group delay dispersion.

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1. Introduction

Short – pulse generation has advanced to a degree where the bandwidth of standard Bragg mirrors limits the pulse width of ultrashort pulsed lasers [1].

In work [2] the double-chirped mirrors (DCM) are used for producing the sub-10 fs pulses. The further reduction of duration of the pulse is possible at reduction of the Bragg grating optical thickness. In papers [3, 4] the analytical design and theory of DCM are present. But in these works only thickness for high refractive index layers is changed.

2. Theory

In this Letter we investigate the chirped mirrors (CM) with change both high and low refractive index layers. In our case we use a structure like [1]. Grating materials are TiO_2 with refractive index $n_h = 2.5$ and SiO_2 with $n_l = 1.5$. The Bragg wavelength $\lambda_B = 800$ nm.

For investigation we use the exact calculation of the transfer matrix M [4]:

$$\begin{pmatrix} A(0) \\ B(0) \end{pmatrix} = M(0, L) \begin{pmatrix} A(L) \\ B(L) \end{pmatrix}, \qquad (1)$$

where L is the length of the medium expressed by the number of layer pairs, A and B are the right and leftward traveling waves, respectively.

The complex reflectivity r_m of the periodic structure for the wave incident from the left side is given by

$$r_m = \frac{A(0)}{B(0)} = \frac{M_{21}}{M_{11}} = \sqrt{R} e^{j\Phi}, \qquad (2)$$

where R and Φ are the amplitude and phase of the reflectivity, respectively.

The group delay GD of the chirped mirror is generally given by $\mathrm{GD}(\omega) = -\partial\Phi/\partial\omega$, where ω is the optical frequency. The group delay dispersion GDD is given by $\mathrm{GDD}(\omega) = \partial GD(\omega)/\partial\omega$.

3. Calculation results

In our case the structure consists of 25 layers. First 12 layers are chirped with $d_h = (k/12)^{o_{ch}} \lambda_B/(4\pi n_h)$, $d_l = (k/12)^{o_{ch}} \lambda_B/(4\pi n_l)$, where o_{ch} is the chirping order. Next 13 layers compose the quarter–wave section with fixed Bragg wavelength. It is necessary to obtain high reflectance over a wavelength range as broad as possible.

Fig. 1 shows the dependence of GD and GDD on the optical wavelength at various meanings o_{ch}. For the second – and third – order CM at the Bragg wavelength GDD equals zero and for fourth – order CM we have a negative and slightly constant GDD with an absolute value 16.7 fs^2.

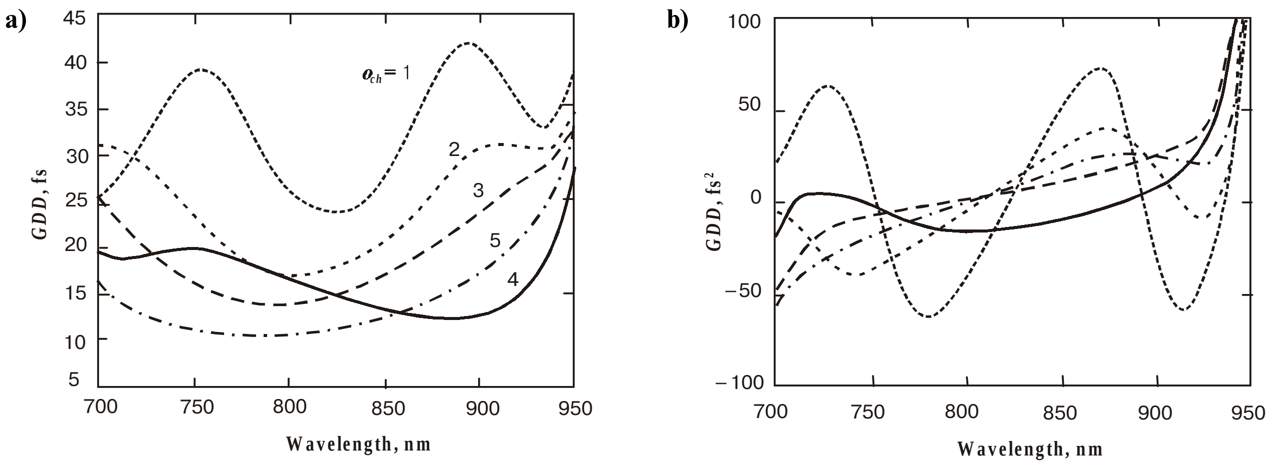

Fig. 1. Group delay (a) and group delay dispersion (b) versus optical wavelength at various values o_{ch}.
Dotted line: o_{ch} = 1; Dashed line: o_{ch} = 2;
Dash-dotted line: o_{ch} = 3; Solid line: o_{ch} = 4;
Dash-two-dotted line: o_{ch} = 5.

Conclusions

The chirping mirrors with chirping both high and low refractive index layers are investigated. The results show the negative and slightly constant group delay dispersion with an absolute value 16.7 fs^2 at the Bragg wavelength for the fourth – order chirping mirrors.

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