Thermal Chirping of Type IIA Fiber Bragg Gratings

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Abstract: - We present a study on thermal chirping of apodized type IIA fiber gratings, concluding about the advantages and limitations of their use as adjustable dispersion compensation devices.

Key-Words: - Optical communications, Fiber Bragg gratings, growth mechanisms, apodization, thermal chirp, dynamic dispersion compensation.

1 Introduction

Several authors have presented dynamically adjustable group velocity dispersion (GVD) compensators with central wavelength control, based on uniform fiber Bragg gratings (FBG) and altering the chirp recurring to strain [1] or temperature gradients [2]. The latter approach allows higher reproducibility and reversibility of the filtering characteristics, although it typically leads to a smaller tuning range and speed.

Typically, type I FBGs [3] are employed in such devices, but higher chirp bandwidths can be achieved recurring to type IIA FBGs [3], with considerably higher temperature sustainability, when compared to type I ones.

Therefore, in this paper we analyze type IIA chirped FBGs (CFBG), trying to conclude about its feasibility and the advantages/disadvantages of its use on the referred GVD compensation devices.

2 Type IIA CFBGs: implementation and experimental results

A 20 mm long type IIA FBG was fabricated in high germanium content (~30 mol%) photo-sensitive fiber (Fibercore SM1500 4.2/125), with the UV beam originated from a Ar^+ laser (244 nm), using the phase mask scanning technique. We have considered a triangular apodization profile, built with 200 steps.

In Fig. 1 we present the FBG measured reflection spectrum and group delay variation, using an optical network analyzer.

Inducing thermal gradients, using a structure with two Peltiers on each side of a Zn channel, we observe in Fig. 2 that increasing the temperature variation will

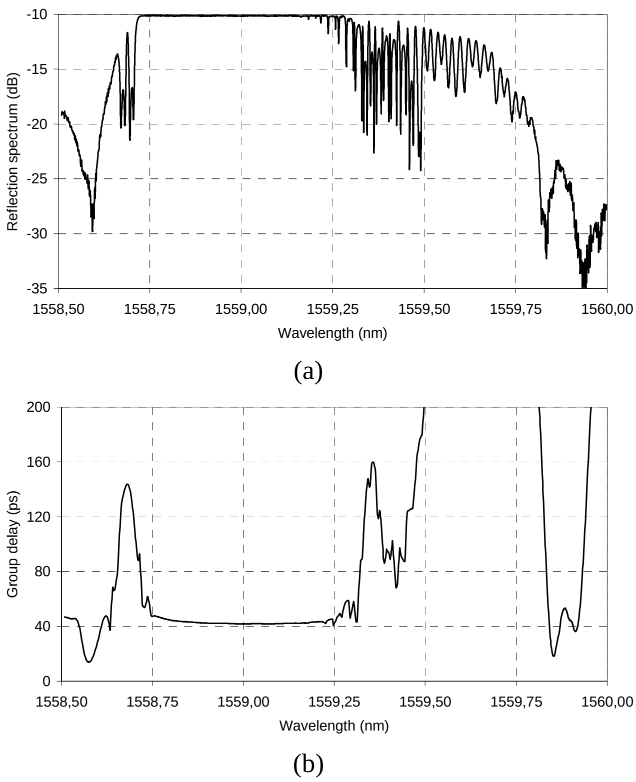
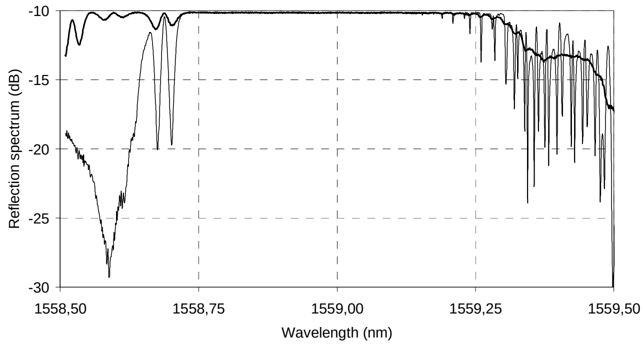


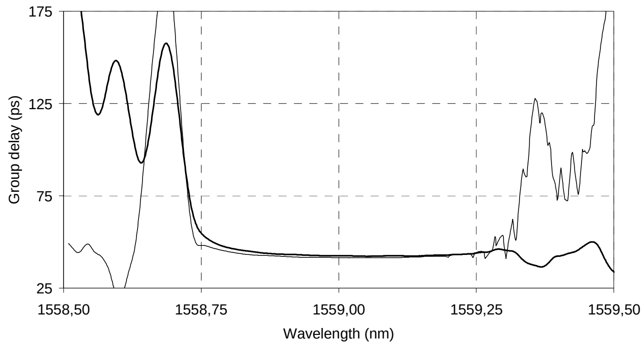
Fig. 1 – Measured reflection spectrum (a) and group delay variation (b) of the implemented apodized type IIA FBG.

lead to the chirp bandwidth increase. The variation on the group delay slope is not so evident, nevertheless it is observed a slightly decrease on it.

This small variation is observed since the implemented grating corresponds to a refractive index perturbation with high kL (L is the grating length and k is a typical parameter usually known as "AC" coupling coefficient) [4] and low mean value



(a)



(b)

Fig. 2 – Measured reflection spectra (a) and group delay variations (b) of the described apodized type IIA FBG, considering different induced thermal gradients: 30ºC – 40ºC (hair line) and 10ºC – 60ºC (heavy line).

variation, and the induced gradients drift is not enough.

In the next section we will analyze this situation, trying to justify the experimental results observed and conclude about the feasibility of type IIA CFBGs.

3 Type IIA CFBGs: simulation

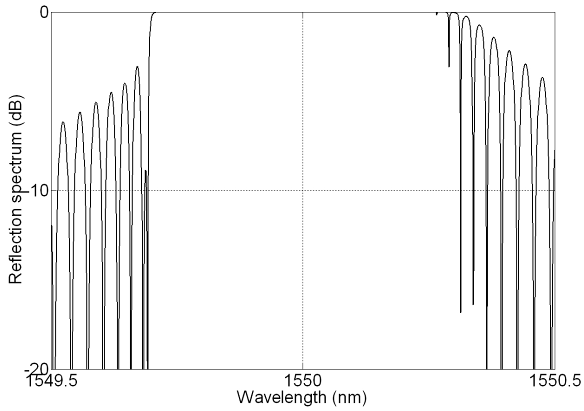
FBGs are based on a perturbation of the effective refractive index, n_{eff}, given by:

$$\delta n_{eff}(z) = \overline{\delta n}_{eff}\; f(z)\left\{ n_{th}(z) + \nu \cos\left[\frac{2\pi}{\Lambda} z + \phi(z)\right]\right\} \quad (1)$$

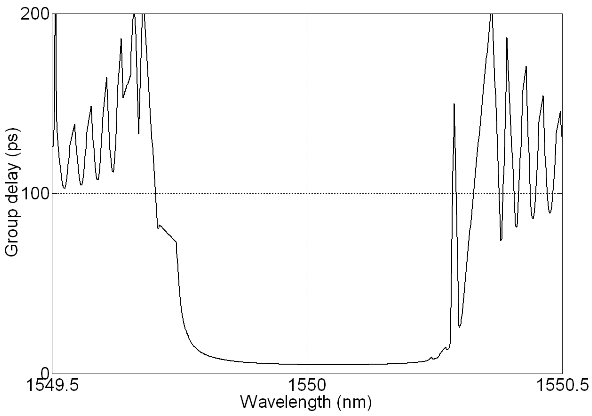
where z represents the distance from the grating input, $\overline{\delta n}_{eff}\, f(z)$ is the apodization profile, with $f(z)$ normalized to a maximum value of 1, ν is the fringe visibility of the index change (ideally 1.0), Λ is the grating period, $\phi(z)$ is the grating chirp and $n_{th}(z)=n_{th}+n_{th}'f'(z)$, describes the variation of the perturbation mean value. For linear chirped FBGs:

$$\frac{1}{2}\frac{d\phi(z)}{dz} = -\frac{4\pi n_{eff}\, z}{\lambda_B{}^2}\frac{d\lambda_B}{dz} \quad (2)$$

with λ_B the Bragg wavelength and $d\lambda_B/dz$ the chirp parameter (nm/cm).



(a)



(b)

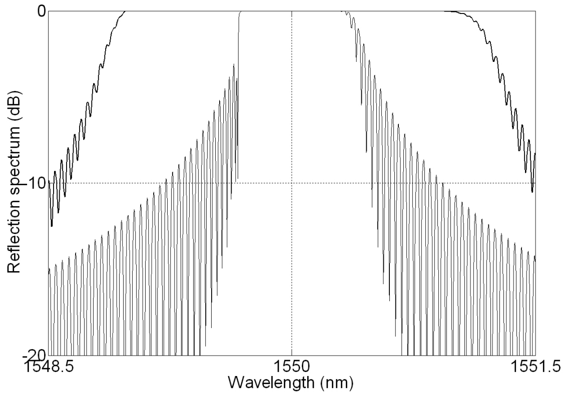
Fig. 3 – Simulated reflection spectrum (a) and group delay variation (b) of the described FBG (L=20 mm, $\overline{\delta n}_{eff}=5\times10^{-4}$, $n_{th}'=-0.2$).

The FBG reflection spectrum results from the coupling between the scattered light travelling in both directions inside the grating, and it can be obtained by solving the Ricatti differential equation [4]. By using this method, the grating reflection spectrum (r), and the group delay ($T_d=\partial\theta_r/\partial\omega$, θ_r=phase(r)), can be obtained.

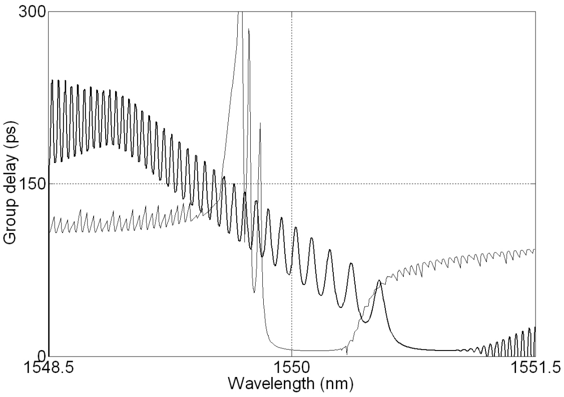
In Fig. 3 we present the simulated response of a grating with an associated perturbation of high kL and low mean value variation, similar to the implemented in section 2.

Considering chirp in the presented grating, and increasing its absolute value, the effect will be the observed in Fig. 4, the increase of the chirp bandwidth. The group delay slope decreases as expected. Notice that the ripple effect is always present, although is decreases as the chirp parameter increases.

These simulations confirm the experimental results. For high kL FBGs, with low variation of the perturbation mean value and high amplitude of the perturbation amplitude on the extremities, chara-



(a)



(b)

Fig. 4 – Simulated reflection spectra (a) and group delay variations (b) of the referred FBG, with chirp parameters of -0.05 nm/cm (hair line) and -0.5 nm/cm (heavy line).

-cteristic of type IIA apodized FBGs, only for high chirp values the observed ripple is reduced to acceptable values.

Nevertheless, type IIA FBGs are the best option for such high bandwidth applications, since the necessary high values of the chirp parameter can only be achieved for gratings with high temperature sustainability (500 ºC for the presented type IIA FBG).

4 Conclusion

We presented a study on type IIA CFBGs, comparing simulation results with experimental ones, and conclude that such gratings can potentially be used as thermo-adjustable dispersion compensation device, with enhanced dispersion/central wavelength tuning range, whenever high chirp bandwidth is needed. For low bandwidth applications type I CFBGs are preferable (lower delay ripple associated).

Acknowledgments

The authors wish to acknowledge Dr. Hans Limberger and its group from EPFL – École Polytechnique Fédéral de Lausanne – for writing the presented type IIA FBG.

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