Design and Fabrication of Fibre Bragg Gratings with V-shaped Dispersion Profile for Multi-Channel Signal Processing

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Abstract *We have designed and fabricated a new type of fibre Bragg grating (FBG) with a V-shaped dispersion profile for multi-channel dispersion compensation in communication links.*

Introduction

Fibre Bragg gratings (FBGs) have a large, and not yet fully explored, potential in optical signal control and processing. A variety of FBG-based devices have already been manufactured for gain-flattening, second- and third-order dispersion compensation and other applications in fibre communications [1, 2]. Novel fabrication technologies, e.g. femtosecond laser inscription, open new practical ways to create sophisticated advanced grating structures. Multi-channel dispersion compensation is of great interest both for in-line and receiver side applications. Periodic group-delay dispersion compensators greatly reduce the timing jitter from inter-channel collisions. As it has been shown in [4], that using dense wavelength-division multiplexing at 10 Gbps channel rate with additional periodic-group-delay dispersion compensation it is feasible to achieve transmission distances of 9000 km with uncorrected (no FEC) bit error rates of 10^{-8}.

In this paper, we present design and fabrication results for a new type of multi-channel FBG with V-shaped dispersion profile. The FBG with V-shaped dispersion was first proposed in [3] as an advanced device for optical pulse processing. Here, we demonstrate a design and fabrication of V-shaped dispersion profile FBGs for *multi-channel* applications in telecom.

Design of FBG with V-shaped dispersion

Powerful design methods [5,6], for instance, the inverse-scattering algorithm make it possible to synthesize FBGs with desired reflection response and phase control. Our target grating response would be:

$$H_R(\delta) = \sqrt{0.95}\exp(-(\delta/\delta_B)^4)\times$$
$$\exp(-j(\beta''/2!)L((c/n_{eff})\delta)^2))\times$$
$$\exp(-j(\beta'''/3!)L((c/n_{eff})\delta)^3))$$

where δ is the detuning parameter between the wave-number of counter-propagating waves and the reference Bragg wave number, δ_B corresponds to the grating bandwidth (here 100 GHz at -3 dB), β'' and β''' are the second- and third-order dispersion coefficients for the fibre, L is the link length, c is the speed of light in vacuum and n_{eff} is the average effective refractive index. By varying the values of β'' and β''' we can achieve different dispersion profiles of the grating response spectrum, including the desired V-shaped or Λ-shaped profile. The β''' coefficient is resposible for the dispersion slope and the β'' coefficient- for the V or Λ peak positions. Figure 1 shows the reflection profile (a), time delay response (b) and the dispersion profile (c) of the modelled grating. Fig. 1d presents the distributed coupling coefficient of the grating.

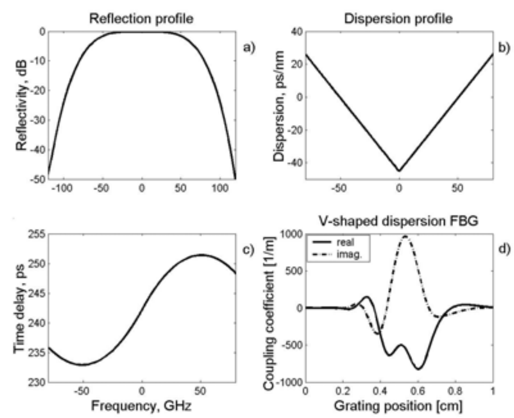

Fig.1 FBG with V-shaped dispersion: a) reflection profile b) dispersion; c) time delay; d) coupling coefficient of the FBG (solid-real part, dashed-imaginary part).

The proposed V-shaped dispersion curve design can be implemented in a way similar to conventional gratings without any additional technical problems.

Experimental results

We fabricated the proposed V-shaped dispersion fibre Bragg grating with a UV direct writing system at Aston University. A frequency-doubled Argon laser at wavelength of 244 nm and a small portion of uniform phase mask with a period of 1071.278 nm was used in the experiment. The apodisation profile and the varied period were realized by appropriately controlling an AO-modulator and moving the fibre. The structure was written in hydrogen-loaded photosensitive fibre. The annealed grating was finally characterized with the Agilent Chromatic Dispersion Test Set (86073C), with the wavelength resolution and the modulation frequency set at 2.5ps and 250MHz, respectively.

Figure 2 shows the reflection profile (a), the time delay response (b) and the dispersion (c) of the fabricated and modelled gratings. It demonstrates a reasonably good agreement between theoretical design and experimental fabrication results.

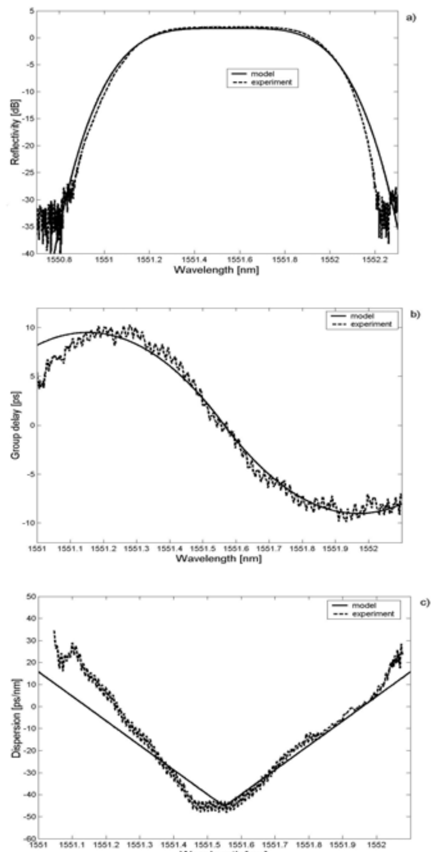

Fig.2 Comparison between modeled and fabricated FBGs: a) reflection profile, b) group delay, c) dispersion (solid line-model, dashed- experiment).

Multi-channel FBG

The multi-channel FBGs have recently attracted great deal of interest in WDM systems as dispersion and dispersion-slope compensators [7-9] for tuneable post-processing at the receiver or in-line application as in [4]. Here we present a novel design of advanced FBG with multi-channel dispersion and dispersion-slope compensation (see an example in Fig. 4). The grating bandwidth is 200 GHz at -3 dB with reflectivity of 95%. It is divided into 4x50 GHz channels with the dispersion variation range about 500 ps/nm through each channel. Again, by varying β''' third-order dispersion coefficient, we can achive different steepness of the dispersion slope, but we have restrictions on β'' second-order dispersion coefficient values in order to obtain a smooth line for the group delay response.

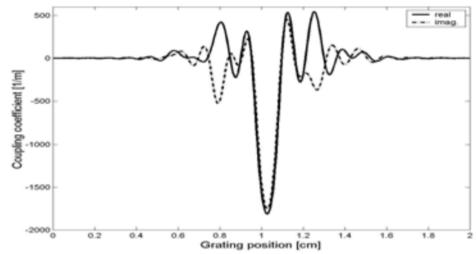

Fig.3 FBG with multi-channel dispersion compensation: (solid line - real part, dashed - imaginary part of the distributed coupling coefficient).

The designed grating (Fig. 3) is non-trivial and quite challenging for fabrication, however, a good agreement between designed and first samples of fabricated FBGs has been achieved (see Fig 4).

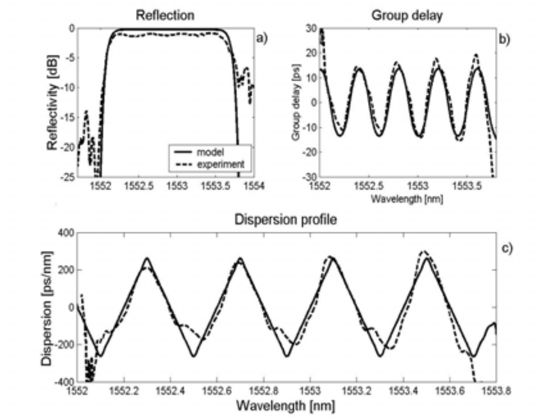

Fig.4 Spectra comparison of modeled and fabricated FBGs: a) reflection, b) group delay, c) dispersion profile (solid model, dashed- experiment).

Conclusions

We have demonstrated new designs and fabrication of V-shaped dispersion profile FBGs with different dispersion slopes. Using the layer peeling algorithm we designed a multi-channel fibre Bragg grating for applications in dispersion-managed high-speed wavelength-division multiplexing systems.

References

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