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LOW-DISPERSION FIBRE BRAGG GRATINGS WRITTEN USING THE POLARIZATION CONTROL METHOD

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***Abstract** We present two fibre Bragg gratings with reduced in-band dispersion for DWDM applications. The gratings were designed by the inverse scattering method and fabricated using the novel polarization control method for UV-writing of advanced gratings.*

Introduction

Due to the growth of the internet and telecommunication over the last decade, there has been an increasing demand for bandwidth. The dense wavelength division multiplexing (DWDM) technology plays an important role for increasing the transmission capacity in optical communication networks. The international standard for the channel spacing has recently been lowered from 100GHz to 50GHz and may become 25GHz in the future at the moderate bit-rate of 10Gbit/s. To meet these demands, the ideal optical filter should have a square spectral response and keep a linear phase throughout the filter pass-band leading to zero cross-talk and low dispersion.

Fibre Bragg gratings (FBGs) are widely used for add/drop multiplexing (ADM). When apodized appropriately, they exhibit a near ideal optical filter function, due to their narrow optical spectrum [1]. However, FBGs suffer from non-linear phase response and thus dispersion both outside and inside the stop-band, which could limit their application in high bit-rate optical communication systems [2]. Recently two alternative ways for reducing the in-band dispersion properties of FBGs have been demonstrated. One is based on an asymmetric sinc-like design [3], while the other one uses a symmetric FBG design applying an optimised cosine progression to the apodization profile [4].

In this paper we present the design and fabrication of low-dispersion asymmetric FBGs. The presented FBGs are written with the novel polarization control method providing an alternative, more robust way of grating fabrication, when compared to the dithering method [3].

FBG design

The inverse Fourier transform of a square filter function gives a sinc-function for the refractive index modulation. However, applying Fourier theory for the design of FBGs is only justified for weak gratings. When dealing with the response of strong FBGs, e.g. when the light in the stop band no longer penetrates the full length of the modulation profile without any significant attenuation, Fourier theory cannot be applied for the full analysis of the spectral response of the FBG. Deviations from the Fourier analysis appear when higher strength FBG with certain properties, e.g. low dispersion, are designed. Several approaches, which are based on the inverse scattering technique, have been developed to address this issue [5].

The target designs of the linear-phase (dispersion free) Bragg grating presented here include zero dispersion throughout the spectral response. Two gratings with a grating length of L=23 mm have been designed, one (a) with a transmission-loss of 60dB and a bandwidth of 100GHz and a second one (b) with a transmission-loss of 20dB and a bandwidth of 50GHz. The modulation profiles were generated by solving the inverse scattering problem by the layer-peeling algorithm implemented in the commercial program IFO_Gratings [6]. Figure 1 shows the normalized refractive index profile for both gratings along with the simulated spectral response and the predicted group delay (launching the light from left to right).

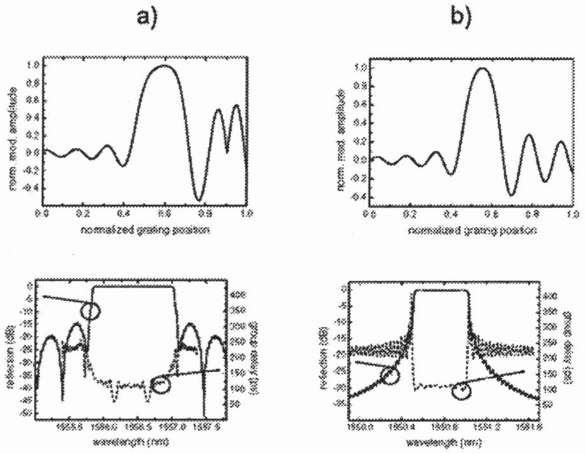

Fig. 1: Normalized refractive index profile for two linear phase FBGs (upper frames) along with the corresponding simulated spectral response and group delay (dashed line) (lower frames).

The refractive index profile is asymmetric and includes multiple phase-shifts. This asymmetry will not affect the amplitude spectral response of the FBG, but will affect the phase response when illuminated from the opposite direction.

Fabrication and group delay measurement

The grating is written using the recently developed polarization controlled method for UV-writing of fibre Bragg gratings (FBGs) [7]. This method relies on changing the polarization of the UV beam during exposure and it requires only a single scan at constant speed with constant UV-fluence. Briefly, a polarization beam splitter is scanning along the phase mask together with the polarized UV-beam. Two spatially separated Bragg gratings are inscripted in the core of the fibre by the diverging s- and p- fraction of the UV-light. A high-power polarizer mounted in a rotation stage controls the polarization of the UV beam and therefore the relative intensities of the UV-light in s- or p-polarization. If the distance between phase-mask and fibre is chosen so that the phase-shift of the two inscripted gratings is equal to π, we are able to write FBGs with advanced apodization profiles including multiple discrete phase-shifts [7].

A deuterium loaded (100bar) highly non linear (HNLF) fibre (from OFS Fitel Denmark) with NA~0.33 is used and a pulsed Excimer laser operating at 248nm and 40 Hz is employed as the UV source.

The group delay has been determined by the phase-shift technique using an external cavity laser as the source and a modulation frequency of 1GHz [8].

Results and Discussion

Fig. 2(a) shows the measured reflection and transmission spectrum along with the group-delay measurements (top frame) for the 100GHz bandwidth linear-phase grating when probed as indicated in Fig. 1(a). The spectral response is confirmed to be near square with a side lobe suppression of 15 dB and a nearly constant transmission loss of 60 dB. Furthermore Fig. 2(a) shows, that the group delay is nearly constant with a small ripple of 30ps and in good agreement with simulations. In Fig. 2 (middle frame) the measured group delay spectrum is also presented when launching the light from the reverse direction. The measured group delay is in excellent agreement with theoretical prediction.

Fig. 2(b) shows the results for the 50GHz bandwidth grating. Also for this design we achieve a near square filter function with a side lobe suppression of 20 dB at an almost constant transmission loss of 20dB. The measured group delay (top frame) is in excellent agreement with the theoretical prediction and the variation is within 20 ps in the reflective bandwidth.

Both gratings exhibit much better dispersion characteristics when compared to "standard" Gaussian or sinc apodized FBGs [3, 4].

Due to the beam size (beam-waist of 0.7 mm) of the used UV-light, the design of the modulation profile was limited to 5 phase-shifts at a grating length of 23 mm. Using a CW-laser with a better mode quality and a smaller beam size could improve the quality of the design and fabrication of FBGs.

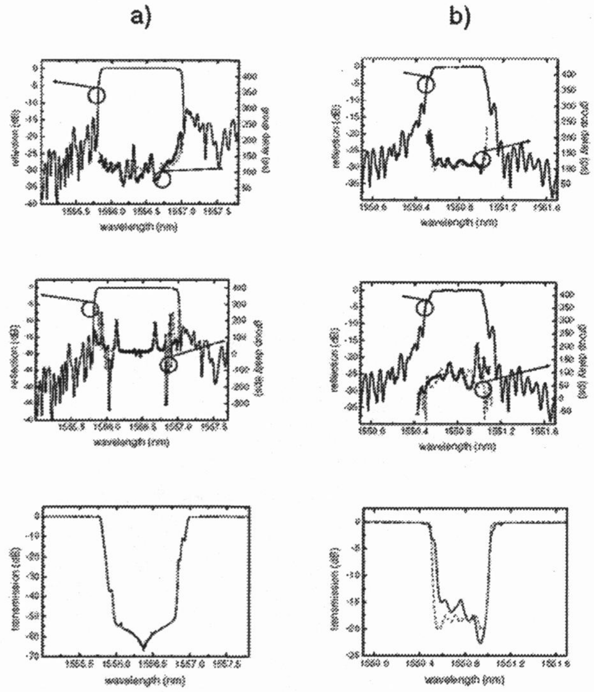

Fig. 2: Measured reflection, group delay and transmission spectra of the two designed linear phase FBGs. Top frames: launching the light from the left (designed); middle frames: launching the light from the right (opposite) direction; lower frames: transmission spectra. The dashed lines represent simulated data.

Conclusions

Dispersion-reduced optical filters using 23mm long FBGs for 100GHz and 50GHz channel spacing in DWDM are presented. Both designs were written with the novel polarization control method and prove that the new writing method is capable of writing advanced, designed FBGs and is only limited by the beam profile and beam size of the UV-source and the non-linear photosensitivity of the fibre.

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