Experimental Demonstration of the Reduction of PDL and DGD in Fibre Bragg Gratings by Using a Twisted-Fibre for the Inscription

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Abstract

We experimentally report the possibility to reduce PDL and DGD in fibre Bragg gratings by inducing polarization mode coupling. This is obtained by using a twisted-fibre for the inscription.

Introduction

Fibre Bragg Gratings (FBG) are recognized as an attractive commercial solution for different telecom applications such as WDM filters, dispersion compensators or gain equalisation filters. For telecom applications, especially in the context of high bit rate transmissions where polarization dependent properties are critical, it is essential to obtain components with low Polarization Dependent Loss (PDL) and Differential Group Delay (DGD) values.

Polarization properties for UV and infrared written gratings as well as for gratings written using a femtosecond pulses laser have been recently analysed both theoretically and experimentally [1,2,3]. These studies report that gratings can exhibit significant PDL and DGD values. In this context, it is therefore important to find solutions to reduce PDL and DGD of these devices. In this paper, we report the possibility to reduce these values by using an original manufacturing technique that introduces polarization mode coupling into the FBG.

Principle of the technique

PDL and DGD are related to the presence of birefringence. In the case of FBG, it is mainly caused by the writing process (photo-induced birefringence); it is typically related to the asymetry of the manufacting process, which comes from the single side-written fabrication and the orientation of the polarization state of the laser source.

A reduction of PDL and DGD can be obtained by minimizing the birefringence. For that purpose, previous studies have reported the possibility to decrease the photo-induced birefringence by using a dual exposure method [4] or by optimizing the polarization of the UV laser [5]. In practice, it is also possible to reduce PDL and DGD by reducing the effects of the birefringence. This can be obtained by inducing polarization mode coupling into the gratings. In this paper, we present and use a manufacturing setup in which the grating is written in a twisted fibre along its axis; the fibre is then relaxed after the writing process. Compared to the technique using untwisted fibre, this method allows to obtain a grating, for which the photo-induced birefringence is the same, that exhibits polarization mode coupling. The degree of coupling is then related to the twist rate. Let us mention that our technique uses the same concept that the one imagined for spun fibres [6].

Preliminary simulation results

Prior to the experimentation, we have simulated the spectral properties of these gratings obtained in twisted fibres. For that purpose, the wavelength dependencies of PDL and DGD were deduced from the Jones matrix of the grating; this latter is obtained by using the classical transfer matrix simulation method [7] including polarization characteristics, i.e. the birefringence value and the polarization mode coupling. The detail of this simulation falls outside the scope of this paper; only final results are depicted in figure 1.

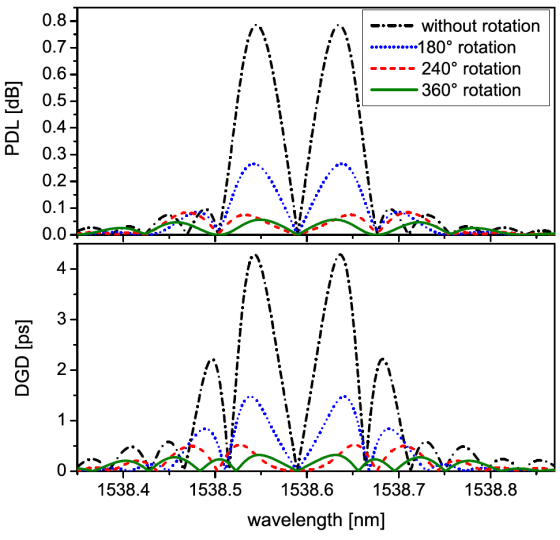

Fig. 1: PDL and DGD of twisted FBG (simulation)

PDL and DGD presented in figure 1 correspond to gratings with constant grating parameters (refractive index modulation = 8.10^{-5}, length = 1 cm), constant birefringence value (8.10^{-6}), but exhibiting different level of polarization mode coupling. In figure 1, the

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rotation angle (in degree) refers to the rotation of the polarization axis (induced by the twist) between the two ends of the grating. As expected, these results globally confirm the intended effect, i.e. the reduction of grating PDL and DGD when the rotation rate increases. Experimental study was then conducted in order to demonstrate this possibility in practice.

Experimental results

Our FBG were written into co-doped boron-germanium photosensible single mode fiber by means of the phase mask technique (single side-written process) using a frequency-doubled Argon-ion laser emitting at 244 nm. In our setup, the polarization state of the UV laser was parallel to the fiber axis in order to minimize the photo-induced birefringence. The gratings are 1 cm long and are characterized by a rejection of about 12 dB.

Fibres used for the inscription were placed in the setup by using two clamps (whose one can be turned) distant of 30 cm. Twisted fibres were obtained by turning the clamp N times. Considering a grating of 1 cm long, the rotation angle between the two grating ends is given by (N/30)*360°.

Four FBG have been manufactured with 4 N values: N = 0 (grating without twist), N = 12, N = 18 and N = 24. The experimental PDL and DGD evolutions with wavelength of these FBG were derived from the measurement of the Jones matrix in transmission (Jones matrix eigenanalysis method [8]). A fully polarized tunable laser source EXFO FLS2600B and a polarimeter Profile PAT9000B were used to measure the Jones matrix. The input light was launched through a polarizer controlled by the polarimeter. These results are depicted in figure 2 where the amplitude response is also represented.

As it can be observed, one important conclusion is that the fabrication of grating in twisted fibre does not distort the amplitude response of the grating. However, it leads to a significant reduction of both the PDL and the DGD of the grating, which is the intended effect. Our experimental results point out a reduction of more that 50% of the maximum of the PDL and the DGD values for the 288° rotation grating compared to the untwisted gratings. Let us mention that the PDL observed out of the grating main band are related to the connectors used in our measurement setup and are not linked to the fibre twist.

Conclusion and acknowledgments

We experimentally report the possibility to reduce PDL and DGD in FBG by using a twisted fibre for the inscription. This technique can then be used to decrease the significant PDL and DGD values associated to FBG, which is recommended in the context of high bit rate transmission systems.

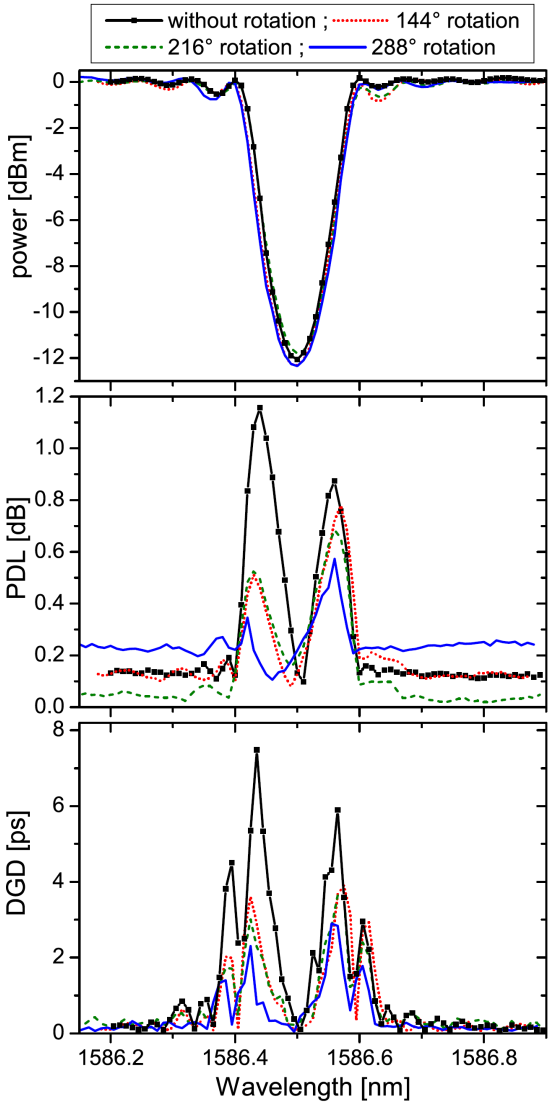

Fig. 2: Transmission power, PDL and DGD of our experimental twisted gratings

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