PDL and DGD Measurements of Mechanically Induced Long-period Fiber Gratings

G. Rego[1,2,3], M. Morais[4], J. L. Santos[2,5], H. M. Salgado[2,3]

1 Escola Superior de Tecnologia e Gestão – Instituto Politécnico de Viana do Castelo, 4900-348 Viana do Castelo, Portugal

2 INESC Porto – UOSE, Rua Campo Alegre, 687, 4169-007 Porto, Portugal

3 Departamento de Engenharia Electrotécnica e de Computadores, FEUP, Rua Dr. Roberto Frias, s/n 4200-465 Porto, Portugal

4 Instituto Electrotécnico Português, Rua de S. Gens, 3717, 4460-409 Senhora da Hora, Portugal

5 Departamento de Física, Faculdade de Ciências, Universidade do Porto, Rua Campo Alegre, 687, 4169-007 Porto, Portugal

Abstract: We have investigated the polarization dependent loss (PDL) and the differential group delay (DGD) of mechanically induced long-period fiber gratings. A birefringence compensation method is also presented.

1. Introduction.

Recently, several techniques to mechanically induce long-period fiber gratings (MLPFGs) have been proposed [1]-[3]. These technologies share the simplicity, the flexibility and the inexpensiveness. The MLPFGs can be performed in any kind of singlemode fibers, without the need to remove its coating, and their attenuation loss can be controlled in real time what makes them very attractive for EDFAs gain equalization [3]-[4]. However, the MLPFGs are intrinsically polarization sensitive and exhibit polarization mode dispersion (PMD) due to linear birefringence caused by external pressures [5]. These properties may depend on a particular fabrication technique.

In this paper, we present results of further investigations on MLPFGs produced by winding a string around a fiber/grooved tube set [1]. PDL and DGD measurements are also presented and a birefringence compensation method is discussed.

2. MLPFGs Fabrication.

Gratings were fabricated placing the fiber on top of a cylindrical tube with grooves separated by 0.6 mm and having a depth of 0.15 mm. Afterwards, a 0.25 mm-diameter nylon string under tension, caused by a mass of 41.8 g, was wound around the fiber/tube set 70 times. Fig. 1 shows the transmission spectrum of the grating as a function of the external loads applied to it. The effect of loading a MLPFG performed in an uncoated fiber is shown in Fig. 2. As it can be seen for weights above 378 g back-coupling occurs, i.e., the energy is coupled to other cladding modes.

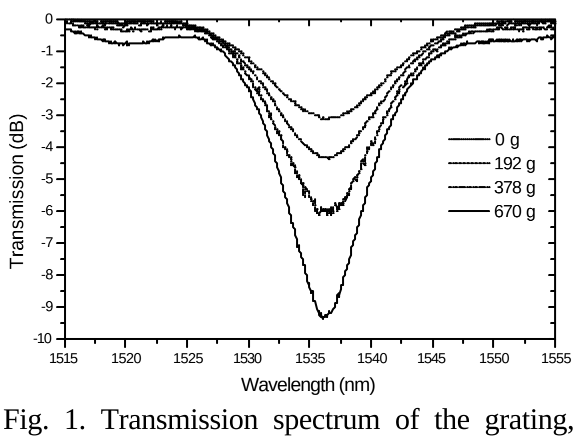

Fig. 1. Transmission spectrum of the grating, induced in a coated fiber, as a function of the applied loads.

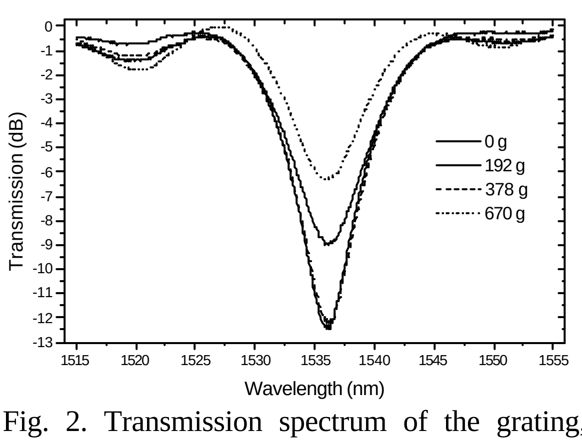

Fig. 2. Transmission spectrum of the grating, induced in an uncoated fiber, as a function of the applied loads.

Gratings formation was attributed to refractive index modulation through the photoelastic effect owing to periodic applied pressure or to microdeformations. However, it is interesting to note that if aluminium paper is placed over the tube before putting the fiber, no grating appears, which means that the pressure caused by the nylon string and by the v-grooves does not play a fundamental role in their growth. Moreover, it was found that if another length of the nylon string was wired around the tube prior to induce the grating by the standard method [1] that would result in an increase of the attenuation of the loss peaks. Therefore, one may conclude that their formation is mainly related with microbending.

3. PDL and DGD Measurements.

Whilst the gratings are being performed, geometric and stress-induced birefringence is introduced to some extent. Moreover, it arises from the phase-matching condition [1] that birefringence leads to a split of the resonance bands for two orthogonal polarizations. On the other hand, the existence of PDL gives rise to DGD through the differential attenuation of the electric fields of two orthogonal polarizations. Therefore, the MLPFGs possess both PDL and DGD.

The gratings PDL was determined using the polarization-scanning method [6], i.e., for each wavelength all polarization states in the Poincaré sphere were virtually generated in order to find the minimum and maximum power transmitted through the grating. The DGD was software calculated from the wavelength dependence of the Jones matrix eigenvalues. The instruments used were a computer controlled polarization analyzer (HP8509B) and an external tunable laser (HP8167A). Fig. 3-6 show the spectral dependence of the PDL and DGD of two gratings produced in the fiber with and without coating for different values of the external applied pressure. It can be seen that the spectral PDL and DGD have similar behaviour and both follow the change of the attenuation of the loss peaks independently of the weights increase (see Fig. 6 and recall back-coupling in Fig. 2). Thus, it might be concluded that DGD is more a result of the existence of PDL then “pure” birefringence.

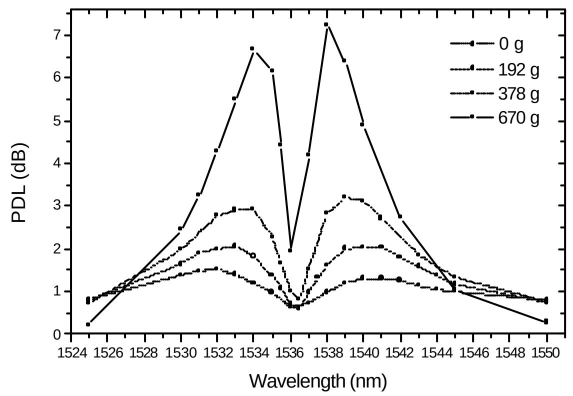

Fig. 3. Spectral PDL of the grating (coated fiber) as a function of applied loads.

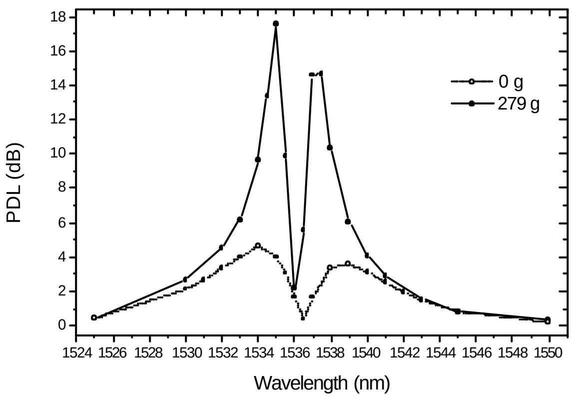

Fig. 4. Spectral PDL of the grating (uncoated fiber) as a function of applied loads.

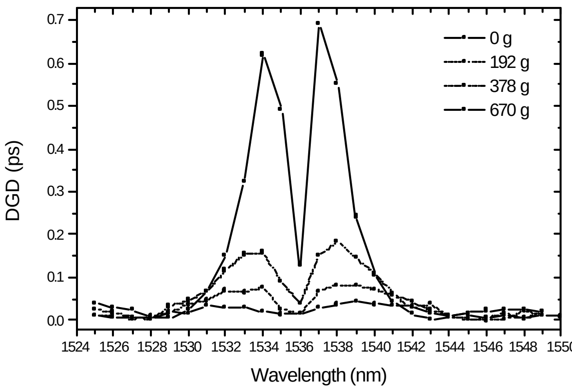

Fig. 5. Spectral DGD of the grating (coated fiber) as a function of applied loads.

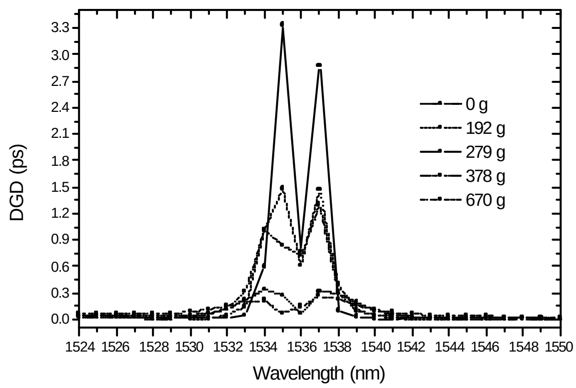

Fig. 6. Spectral DGD of the grating (uncoated fiber) as a function of applied loads.

It was experimentally verified that, for each wavelength, the two principal states of polarization, that corresponds to a maximum and to a minimum are not orthogonal which confirms that MLPFGs possess both PDL and DGD. The PMD is in general determined as an average of the DGD, but in the presence of PDL their relationship is non trivial [7].

Notice that for a specific attenuation loss required, lower PDL and DGD values are obtained if one removes the fiber coating or increases the tension on the nylon string instead of increasing the loads. The configuration which consists in the wind of the nylon string before performing the grating by the standard method also leads to lower PDL and DGD values.

4. Birefringence Compensation.

In order to investigate the possibility to compensate the birefringence of the MLPFGs, two similar gratings were simultaneously performed fixing the fiber on the top and on the bottom of the grooved tube prior to the wind around of the nylon string. The coating of the fiber was removed on purpose to obtain DGD values well above the random noise. Fig. 7 shows the transmission spectra of the top, the bottom and of both gratings. The gratings DGD is also shown in Fig. 7. Afterwards, a half wave plate was inserted in between the gratings, to rotate the polarization, and the maximum value of the DGD was measured as a function of the rotation angle (Fig. 8). As it can be seen although it was not possible to fully compensate the birefringence, maybe due to non-identical gratings, a considerable reduction was obtained. Another approach based on the twist of the fiber was presented in Ref. [5].

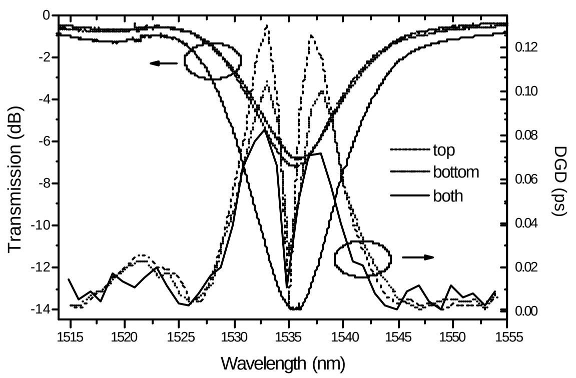

Fig. 7. Gratings transmission spectra and the correspondent DGD.

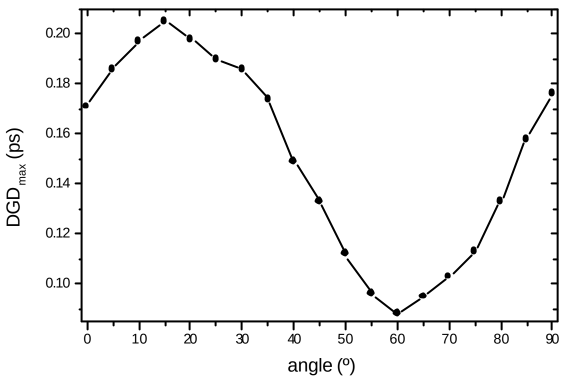

Fig. 8. Maximum value of DGD as a function of the rotation angle.

5. Conclusions.

MLPFGs produced through the wind of a string around a fiber/grooved tube set may exhibit high values of PDL when performed under certain conditions where, for particular wavelengths, an 18 dB of extinction ratio was achieved. However, for moderate values of attenuation loss a proper choice of the performing parameters and/or method, which avoids the use of loads, results in lower PDL values. Therefore, taking also into account that a considerable reduction of the DGD is obtained when a birefringence compensation method is implemented, it seems reasonable to admit the use of MLPFGs as gain equalizers.

Acknowledgments.

G. Rego is thankful for the grant through the Program PRODEP III - Medida 5 - Acção 5.3. - Formação Avançada de Docentes do Ensino Superior, integrada no Eixo 3.

References.

[1] G. Rego, J. R. A. Fernandes, J. L. Santos, H. M. Salgado, and P. V. S. Marques, “New technique to mechanically induce long-period fibre gratings” *Opt. Commun.*, vol. 220, pp. 111-118, May 2003.

[2] S. Savin, M.J.F. Digonnet, G.S. Kino, and H.J.Shaw, “Tunable mechanically induced long-period fiber gratings”, *Opt. Lett.*, vol. 25, pp. 710-712, May 2000.

[3] I. Sohn, J. Baek, N. Lee, H. Kwon, and J. Song, “Gain flattened and improved EDFA using microbending long-period fibre gratings”, *Electron. Lett.*, vol. 38, pp. 1324-1325, Oct. 2002.

[4] M. Tachibana, R.I. Laming, P.R. Morkel, and D.N. Payne, “Erbium-Doped Fiber Amplifier with Flattened Gain Spectrum”, *IEEE Photon. Technol. Lett.*, vol. 3, pp. 118-120, Feb. 1991.

[5] J.Y. Cho, K.S. Lee, “A birefringence compensation method for mechanically induced long-period fiber gratings”, *Opt. Commun.*, Vol. 213, pp. 281-284, Dez. 2002.

[6] Y. Zhu, E. Simova, P. Berini, and C. P. Grover, “A comparison of Wavelength Dependent Polarization Dependent Loss Measurements in Fiber Gratings”, *IEEE Trans. Instrum. Meas.*, vol. 49, pp. 1231-1239, Dec. 2000.

[7] B. Huttner, C. Geiser, and N. Gisin, “Polarization-Induced Distortions in Optical Fiber Networks with Polarization-Mode Dispersion and Polarization-Dependent Losses”, *IEEE Trans. Instrum. Meas.*, vol. 6, pp. 317-329, Mar. 2000.