BIREFRINGENCE EFFECT IN UNIFORM FIBRE BRAGG GRATINGS

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ABSTRACT

This work studies the birefringence induced in a uniform fibre Bragg grating by application of a transversal load. When the load increases, the reflected spectrum broadens for forces below 30 N and above these values the Bragg wavelength peak splits into two. These two peaks are related to refractive index changes in the geometry of the fiber produced by the transversal load.

1. Introduction

Fibre Bragg gratings (FBG) are usually written in very low birefringence fibres because induced or accidental birefringence is a disadvantage in most applications. However, birefringence in uniform FBGs can be useful to emulate and compensate Polarization Mode Dispersion (PMD) in optical communications systems [1,2,3]. In this work, birefringence is induced in a uniform FBG using transversal load. Therefore, a differential group delay and a division and/or split of the Bragg reflection peak in the orthogonal components that propagate through the grating are also induced.

2. Experimental Setup

In Figure 1 shows the experimental setup used for stress application, which is responsible for the induced birefringence. The FBG was mounted in aluminium and plastic plates to ensure that the mechanical process will not break the FBG. Two dummy optical fibres were glued at the extremes of the plate to guarantee the alignment and the stretched position when transversal load was applied. All the three fibres are without coating avoiding stress relaxation behaviours. The transversal load was measured in terms of the compression length (Δd), as shown in Figure 1. When the aluminium plates squeezed the fibres, the transversal load increased, thus generating birefringence due to the change of the effective refraction index on both orthogonal propagation axes. The two Bragg reflection peaks obtained through the applied pressure were related to the force induced on the FBG as shown in Figure 2. A theoretical procedure can be done to determine the force applied to the FBG [4]. The elasticity solution for stress along the central axis in a disk is given by

$$\sigma_x = \frac{2F}{\pi h D} \qquad \text{and} \qquad \sigma_y = \frac{6F}{\pi h D} \tag{1}$$

where D is the fibre diameter (considered as 125 μm), *h* is the length of the aluminium stress plate and *F* is the applied force. Applying Hooke's law, the stress state for plane strain is given by

$$\varepsilon_x = \frac{1+\upsilon}{E}\left(\sigma_x\left(1-\upsilon\right)-\upsilon\sigma_y\right) \quad \text{and} \quad \varepsilon_y = \frac{1+\upsilon}{E}\left(\sigma_y\left(1-\upsilon\right)-\upsilon\sigma_x\right) \tag{2}$$

In the case of silica the Young's modulus (*E*) and Poison ratio (ν) are 70 GPa and 0.19, respectively. The change in wavelength can be stated as

$$\frac{\Delta\lambda_x}{\lambda_B} = -\frac{1}{2}n^2\left(P_1\varepsilon_x + P_2\varepsilon_y\right) \quad \text{and} \quad \frac{\Delta\lambda_y}{\lambda_B} = -\frac{1}{2}n^2\left(P_1\varepsilon_y + P_2\varepsilon_x\right) \tag{3}$$

where $\Delta\lambda_{x,y}$ is the wavelength difference from each of Bragg reflection peak of orthogonal propagation axes, λ_B is the Bragg wavelength without any compression, $n = 1.45$ is the average of refraction index in the FBG, and $P_1 = 0.113$ and $P_2 = 0.252$ are the strain-optic coefficients. Considering the information of the wavelength difference we can easily obtained, through equations (1),(2) and (3), the applied force for each compression length case.

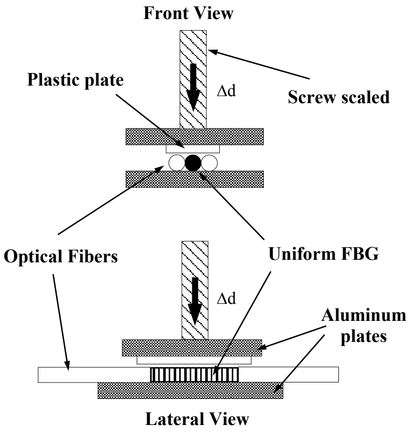

Figure 1 – Experimental set-up for stress application.

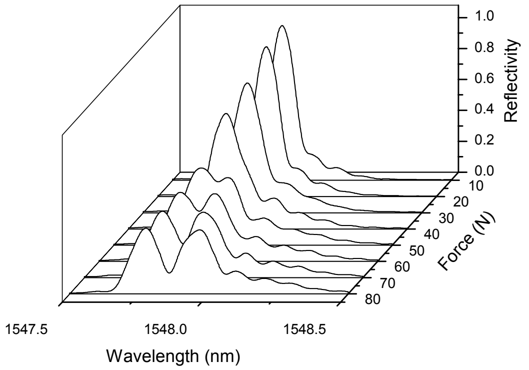

Figure 2 – Normalized FBG reflected intensity spectrum for several applied force values.

3. Results

Figure 3, shows the peak Bragg wavelength separation due to the applied transversal load. The peak Bragg wavelength separation can only be distinguished for forces above of 30 N. Below this value only a broadening of the reflected spectrum is detected. As the transversal load increases the geometry of the fiber changes and also the refractive index in the directions perpendicular to light propagation in the fibre, producing thus an induced birefringence. This birefringence can be calculated through the following relation,

$$\lambda_{SlowAxis} - \lambda_{FastAxis} = 2\Lambda\beta \tag{4}$$

where Λ is the phase mask period, and $\lambda_{SlowAxis}-\lambda_{FastAxis}$ is the difference between the Bragg wavelength peaks reflected in each principal axis. The maximum peak separation achieved was approximately 0.22 nm corresponding to a birefringence of 3.3×10^{-4}. In Figure 4 a linear dependence of birefringence against the applied force (with a slope of 2.4×10^{-5} N^{-1}) is shown.

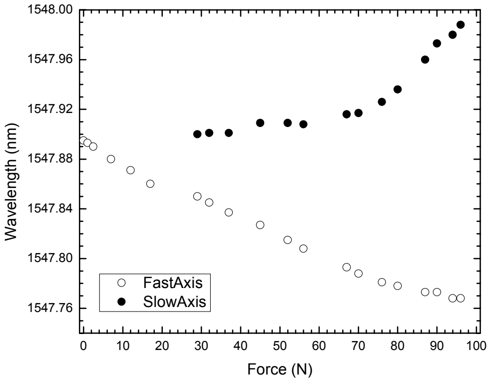

Figure 3 – Peak Bragg wavelength bifurcation against applied force.

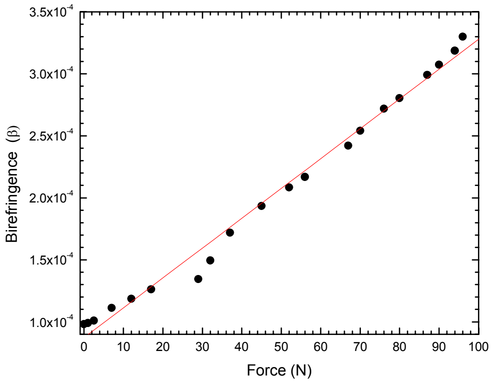

Figure 4 – Induced birefringence against applied force.

4. Conclusions

Birefringence effect in uniform fibre Bragg grating is achieved through a transversal force. The distinguishable bifurcation of the Bragg wavelength occurs for loads greater than 30N. The maximum birefringence achieved was 3.3×10^{-4} for a force of 96 N.

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