Bragg Grating Package for Simple Broad-range Tuning

M. R. Mokhtar (1), M. Ibsen (1,2), S. A. Butler (1), S. Y. Set (3), D. J. Richardson (1,2), D. N. Payne (1,2)
1 : Optoelectronics Research Centre, University of Southampton SO17 1BJ, UK (Email: mrm@orc.soton.ac.uk)
2 : Southampton Photonics Incorporated, Southampton SO16 7NS, UK (Email: mi@orc.soton.ac.uk)
3 : Micron Optics Incorporated, Atlanta GA 30345, USA (Email: syset@micronoptics.com)

Abstract *A tunable package for fibre Bragg gratings is proposed and demonstrated. Reliable and stable axial compression is achieved using this with up to 29nm of continuous tuning with a precise and repeatable tuning algorithm.*

Introduction

Currently, there are numerous applications of fibre Bragg gratings and related devices in both telecommunications and sensing fields. Their rapid advancement owes to the inherent fibre compatibility and the flexibility they offer for achieving desired spectral characteristics. Furthermore, a definite evolution of the optical transmission systems to dynamically reconfigurable networks brings about the need for this attractive component to acquire an additional feature of tunability.

The Bragg wavelength of a grating can be altered by changing its period or by changing the index of refraction of the waveguide host. These changes typically can be induced either thermally or mechanically. The achievable tuning range is limited by the tolerable extremes of either of these. This has motivated extensive research into techniques for truly tunable fibre Bragg gratings, a search which recently discovered more appropriate techniques that exploit compression [1]-[2]. The tuning range remarkably has been extended to 45nm, but previous demonstrations typically have required both complicated and bulky components to perform the tuning action. A much simpler tuning technique recently has been reported by S. Y. Set et. al., which uses a beam bending technique [3].

In this paper, we demonstrate the design and construction of a simple tunable package based on the beam bend-tuning technique. We show its tuning capabilities and application in a “set and forget” configuration with up to 29nm compression-tuning.

Device description and experiment

In accordance to [3]-[4], uniform compression of a fibre grating can be achieved by bending the fibre grating at an arc of length *L*, with the fibre grating embedded in a flexible material slightly displaced from the neutral axis at a distance *d*. The relative compression/extension of the fibre grating then is given by

$$\varepsilon = -\frac{d.\theta}{L}\ ,\ \ L \neq 0 \qquad (1)$$

where θ is the central angle of a sector of a circle, formed by the arc. It follows that the Bragg wavelength detuning obeys the following rule:

$$\Delta\lambda \approx (1 - p_e)\varepsilon.\lambda_B \qquad (2)$$

where λ_B is the Bragg wavelength of the fibre grating in idle state and $p_e \approx 0.22$ is a photoelastic coefficient.

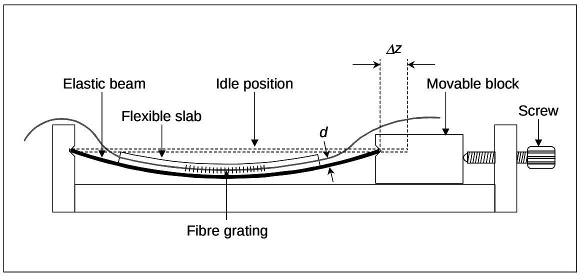

Fig. 1. Schematic structure of the tunable package

The schematic structure of our tunable package based on compression is illustrated in figure 1. The fibre Bragg grating is embedded in a flexible material, which is firmly fixed onto a straight elastic beam of length *L*. An arc is obtained by horizontally shifting one end of the elastic beam inwards, while fixing its other end. The horizontal displacement, Δz of the shifted end to form an arc with a desired sector angle θ is given by

$$\Delta z = L \times \left(1 - \frac{\sin(\theta/2)}{\theta/2}\right) \qquad (3)$$

The mutual dependence of Bragg wavelength detuning and horizontal displacement of the beam edge on the sector angle correlates the two parameters. Thereby, the operation wavelength of the fibre grating can be accurately determined for a given displacement.

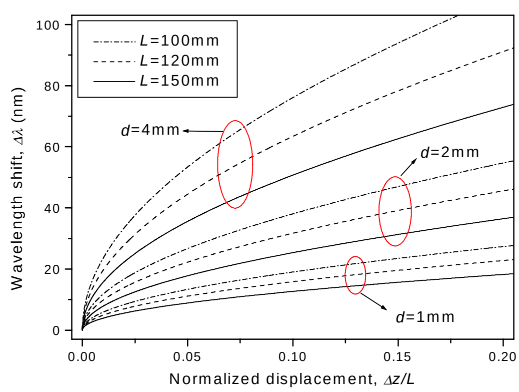

Fig. 2. Wavelength detuning characteristics against normalized displacement for different d and L

Figure 2 illustrates the wavelength detuning against normalized displacement, $\Delta z/L$ for different values of d and L. It implies that even for moderate values of d, it is possible to produce wavelength detunings in access of 50nm for only small Δz.

This correlation is experimentally confirmed by varying certain parameters in a packaging configuration. During the tuning procedure, the output powers and spectral response of a fibre Bragg grating are monitored and recorded with a resolution of 0.01nm on an optical spectrum analyser. The demonstration takes into consideration the off neutral axis displacement, d of 2.16mm, 2.18mm, 2.32mm and 2.80mm. The fibre Bragg gratings used are of various lengths L_g, which are 5mm, 10mm and 20mm whereas the lengths of the beams are 100mm and 154mm. The measured wavelength responses are plotted with their corresponding theoretical curves in figure 3. It positively verifies that this parameter complies with the aforementioned relationships. In particular, figure 3(b) demonstrates that wavelength detuning of 29nm can be easily achieved using this device.

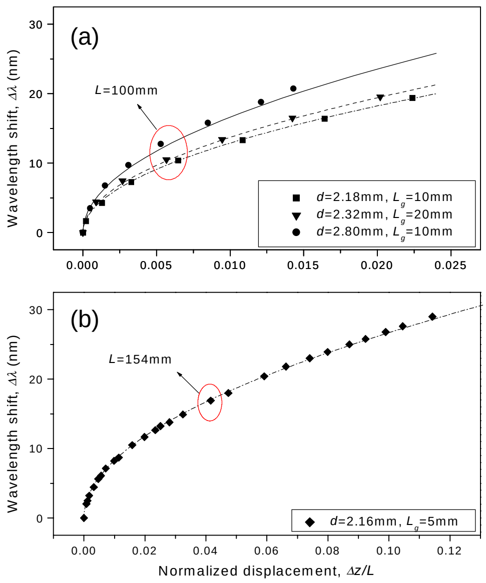

Fig. 3. Overlay of the measured wavelength detunings (symbols) and their corresponding theoretical curves for different d and L

The uniformity of the compression is also investigated in this study. Figure 4 shows excellent match between the spectra of a 5mm fibre Bragg grating in its idle and compressed states, which indicate no chirp is induced upon bending. It is therefore confirmed that the compression is uniform. Equally uniform compressions are possible in longer fibre gratings as devices with length of up to 20mm are shown to exhibit excellent agreement with theory (figure 2 and 3). Additionally, there is no noticeable spectral deformation when back in the idle state, even after repeated tuning. This reversible behaviour can only remain as long as the beam is linearly elastic. Therefore, it is necessary to constrain the inward horizontal displacement to be below the proportionality limit of the beam. Consequently, this requirement puts a limit to the achievable tuning range. However, this limit is way beyond the erbium band, as also indicated in figure 2 when $d \geq 1.5$mm.

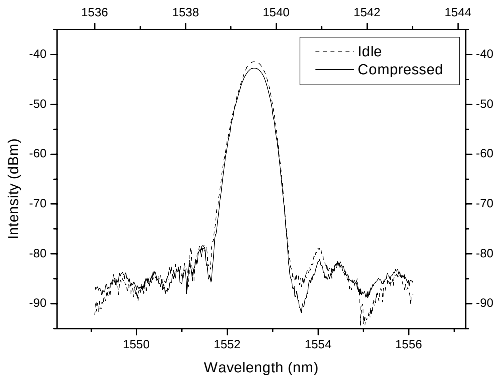

Fig. 4. Spectral response of a 5mm fibre Bragg grating in idle and compressed states (dashed line: bottom axis, solid line: upper axis)

Thermal performance of the compressor is also monitored during the experiment. An anticipated increase in the temperature sensitivity is observed, which is due to the fact that the material embedding the fibre grating is firmly adhered to the beam. As a result, the overall thermal expansion coefficient of the arc structure practically takes the value that of the beam. Nevertheless, this variation can be minimized through astute choice of the beam material.

Conclusions

We have demonstrated a simple package for accurate broad-range tuning of the operational wavelength of a fibre Bragg grating, adapted from the beam bending technique. It demonstrates uniform and repeatable compression for wavelength detunings up to 29nm in precise agreement with the theoretical analysis.

References

1 G. A. Ball et al, Opt. Lett., 19 (1994), 1979-1981

2 A. Iocco et al, J. Lightwave Technol., 17 (1999), 1217-1221

3 S. Y. Set et al, Proc. OFC'01, MC4 (2001)

4 M. Ibsen et al, IEEE Photon. Technol. Lett., 14 (2002), 21-23