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A TEMPERATURE COMPENSATION PACKAGE FOR OPTIC FIBRE GRATINGS

FIELD OF THE INVENTION

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The present invention relates to a temperature compensation package for optic fibre grating elements. In particular, the invention relates to a temperature compensation package for a fibre Bragg grating. The fibre Bragg gratings can be uniform gratings, chirped gratings and blazed gratings.

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BACKGROUND OF THE INVENTION

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Fibre Bragg gratings (referred to as gratings for convenience) are promising components for applications in wavelength division multiplexing fibre communication systems, dispersion compensation, laser stabilization and gain flattening in erbium doped fibre amplifiers, etc. In these applications, the stabilized wavelength reference is highly desirable. Unfortunately, the central wavelength of the grating is sensitive to a number of physical parameters (e.g., temperature, strain, etc). Performance of the grating may therefore vary due to changes in these parameters. Thus, it is of practical importance to develop means to maintain grating performance under varying operating conditions.

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The central wavelength of the grating is shifted when the temperature T or the strain ε that applied to the grating is changed. The change in the wavelength $\Delta\lambda$ can be expressed as:

$$\Delta\lambda = (\alpha + \xi)\lambda\Delta T + (1 - p_e)\lambda\varepsilon \quad (1)$$

where ΔT is the change in the grating temperature;

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- λ is the central wavelength of the grating;
 α is the coefficients of thermal expansion of the fibre containing the optical grating;
 ξ is the thermo-optic coefficient of the fibre containing the optical grating, and
5 p_e is the effective photo-elastic constant of the fibre.

The first term in equation (1) is the inherent temperature dependence of the grating. The second term measures the effect due to the strain on the optical fibre containing the grating. As can be seen from equation (1), one can choose
10 suitable strain to compensate for the change in the wavelength of the grating with the temperature.

Based on this principle, various passive packages have been proposed to
15 stabilise the central wavelength of the grating against the effect of the temperature. For example, US Pat. No. 6044189 describes an apparatus that can provide temperature compensation for the grating. The apparatus comprises a stack of two members with each member having an interface surface bonded to an interface surface of each adjacent member. Both members have two different
20 temperature coefficients of expansion. The grating is attached to a mounting surface on the first member in the stack. The mounting surface is located on the opposite side of the first member from the interface surface. The device forces an elongation of the grating with decreasing temperature, or a shortening of the grating with increasing temperature, which compensates for the change in the
25 wavelength of the grating with a change in temperature.

US Patent No. 5694503 describes a device that comprises a support member and the fibre grating that is attached to the support member. The support member is selected to have a negative coefficient of thermal expansion,
30 which compresses the fibre grating as the temperature increases. US Patent

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5991483 also describes a package which comprises two threaded members with different thread counts to control axial strain on the grating for temperature compensation.

5 While the method described in US Patent No. 5694503 is simple, it is not easy to adjust the support member in order to acquire better grating performance against temperature. In addition, both the US patents are relatively complex in mechanical design requiring suitable coefficients of thermal expansion.

10 SUMMARY OF THE INVENTION

The present invention provides a temperature compensation package for a fibre grating element, comprising a member connected to said fibre grating element for transmitting a force to said fibre grating element, said member adapted to be flexed to adjust the force transmitted to said fibre grating element, and means to control said flexing of said member.

20 By providing a member to transmit force to the fibre grating element which can be controllably flexed, the invention provides a structure for producing tension or compression strain in the fibre grating element to compensate for a change in the centre wavelength of the fibre grating element caused by a variation of temperature.

25 It is preferred that the control means flexes said member to form an arcuate shape. In a preferred embodiment, the member is initially arcuate in shape.

The control means is preferably a temperature compensating element which responds to a variation in temperature to control the force applied to the

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fibre grating element. Alternatively, the control means can be an actuator to actively control the force applied to the fibre grating element.

5 Preferably, the member is a flexible surface on a first beam. The flexible surface preferably has a groove for receiving the fibre grating element. This inhibits damage to the fibre grating element. In a preferred embodiment, the groove is V-shaped in cross-section.

10 It is preferred that the control means has a positive or negative coefficient of thermal expansion. In one preferred embodiment having a control means with a positive coefficient of thermal expansion, the control means and the flexible surface connecting the fibre grating element are located on the same face of the first beam. In another preferred embodiment, the control means and the flexible surface connecting the fibre grating element are located on opposing faces of the
15 first beam.

20 Preferably, the first beam is connected to a second beam. The control means is preferably located between the first beam and the second beam. In one preferred embodiment, the control means is centrally located between the first beam and the second beam. The first beam and the second beam can be connected at their respective ends.

25 The width of the first beam is preferably more than or equal to the width of the second beam. This reduces the risk of damage to the fibre grating element from contact with the second beam. The length of the first beam and the length of the second beam each can be more than the length of the fibre grating element.

30 The fibre grating element can be connected to the flexible surface via a section of optic fibre containing the fibre grating element. This connection may

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be by several methods. For example, the optic fibre section can be supported on the flexible surface. The optic fibre section can also be bonded to or embedded in the flexible surface.

5 The first and second beams can be made of flexible material. In a preferred embodiment, the two beams are made of mechanically flexible material. The first and second beams can have the same coefficients of thermal expansion. The first and second beams can also be relatively thin.

10 In application, it is advantageous to use a member having a positive coefficient of thermal expansion because such members with this property are widely available. However, materials having negative coefficient of thermal expansion over a wide temperature range are also suitable and available for use in the invention. The benefit of such materials is that they are both inexpensive
15 and reliable. The invention provides an environmentally stable package against the temperature which can be made from inexpensive materials and without strict precision.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Preferred embodiments of the invention will now be described, by way of example only, by reference to the drawings, of which:

Fig.1 is a perspective view of a temperature compensation package for a
25 fibre grating element according to a preferred embodiment of the invention;

Fig. 2 is a top view of the package of Fig. 1;

Fig. 3 is a perspective view of an alternative embodiment of the
30 temperature compensation package of Fig. 1;

Fig. 4 is a top view of the package of Fig. 3;

Fig. 5 is a perspective view of another embodiment of the temperature
5 compensation package of Fig. 1;

Fig. 6 is a perspective view of a further embodiment of the temperature
compensation package of Fig. 1; and

10 Figs. 7A, 7B and 7C are top views of the first beam, second beam and the
fibre grating element mounted on the first beam, respectively, of the package of
Fig. 1.

15 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figs. 1 and 2 show a temperature compensation package 1 according to a
preferred embodiment of the invention. Package 1 has a first beam 11, a second
beam 22 and control means 44.

20 Beams 11, 22 are made from thin, flexible material and are arcuate in
shape. Beams 11, 22 are bonded at their respective ends 55, 66 using suitable
bonding material, such as an epoxy agent.

25 A section of optic fibre 33 containing a fibre grating element 13 is located
in grooved surface 12 of flexible beam 11. Surface 12 is, by virtue of being
integrally formed with flexible beam 11, connected to grating element 13 via fibre
section 33 so as to transmit force to grating element 13. Surface 12 acts as a
member that can be flexed to adjust the force transmitted to the grating element
13. The width of first beam 11 is larger than the width of second beam 22 to

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allow surface 12 to flex (and so apply force to fibre grating element 13) unhindered by any contact with second beam 22.

Control means 44 is centrally located between beams 11, 22 and controls the flexing of surface 12 of beam 11. Other locations are possible in between the two ends of the beams 11, 22. Control means 44 in this embodiment is a cylindrical bulk strain adjustment member which is responsive to changes in temperature. Alternatively, control means 44 can be an actuator which actively controls flexing of surface 12 on beam 11. The strain adjustment member 44 can be made from metal and glass materials with large coefficients of thermal expansion.

In the embodiment shown in Figs. 1 and 2, strain adjustment member 44 has a large positive coefficient of thermal expansion. Strain adjustment member 44 is bonded to respective interface surfaces 24 of the first beam 11 and the second beam 22. The sizes of the interface surfaces 24 vary with the cross-sectional area of the strain adjustment member 44.

The package 1 operates as follows. As the adjustment member 44 is inserted between beams 11, 22, a compression strain is applied to beams 11, 22, causing them to flex or bend in an arcuate shape. Surface 12 also flexes, transmitting this compression strain force to optic fibre section 33 and grating element 13. As the temperature of the package 1 increases, the length of the adjustment member 44 expands. This causes adjustment member 44 to apply further compression against beams 11 and 22. This is transmitted by surface 12 to fibre section 33 and grating element 13, causing further compression of grating element 13. This increased compression strain on grating element 13 compensates for the effect of the increasing temperature. Thus, the central wavelength of the fibre grating element 13 is held constant against the increase in temperature.

Conversely, as the temperature of package 1 decreases, the adjustment member 44 contracts, reducing the flexure on beam 11 and so surface 12. This reduction in force is transmitted by surface 12 to grating element 13, relieving the compression strain on the grating element 13. Thus, the central wavelength of the grating is shifted to a longer wavelength thereby compensating for the effect of the decreasing temperature.

Figs. 3 and 4 illustrate an alternative embodiment of the package of Fig. 1. In this embodiment, adjustment member 44' has a negative coefficient of thermal expansion and optic fibre section 33' containing fibre grating element 13' is located on the underside surface 12' of flexible beam 11'. That is, the flexible surface 12' connecting grating element 13' is on the opposing face of beam 11' to the face of adjustment member 44'.

This alternative embodiment works in a similar manner to that described above. In this case, when the adjustment member 44' is inserted between the beams 11', 22', a tension strain is applied to flexible surface 12'. Surface 12' transmits this force to fibre section 33' and fibre grating 13'. As the temperature of the package 1' increases, the length of the adjustment member 44' contracts. Thus, the tension strain on surface 12' (via beam 11') is relieved and this is transmitted to fibre grating 13'. This results in decreasing strain in the fibre grating element 13' compensating for the change in the central wavelength of the grating element 13' with the increasing temperature. Likewise, when the temperature of the package 1' decreases, the length of the adjustment member 44' expands and this expansion is transmitted by surface 12' to grating element 13'. As a result, the strain on the grating element 13' increases. The increased strain on grating element 13' compensates for the effect of the decreasing temperature on the central wavelength.

Fig. 5 illustrates another embodiment of the invention. In this embodiment the width of beams 11", 22" are the same. As a consequence, holes 7", 8" are provided in beam 22" to allow optic fibre section 33" to pass through the package 1". In addition, adjustment member 44" is located near fibre section 33" and grating element 13".

Fig. 6 illustrates a further embodiment of the invention. In this embodiment, package 10 is designed to cater for multiple optic fibre sections 33, 34, 35, 36, 37, 38, 39, 40 each containing fibre grating elements 13. In such a case, the adjustment member 44 has a large coefficient of thermal expansion to provide sufficient force to be transmitted to each fibre grating element 13. While this embodiment is illustrated with an adjustment member 44 having a positive coefficient of thermal expansion, a similar package for multiple optic fibre sections can be made using an adjustment member with a negative coefficient of thermal expansion.

Figs. 7A, 7B and 7C shows in more detail the individual components of the package 1. Figs. 7A and 7B show top views of the first beam 11 and the second beam 22, respectively. Where only one optical fibre section 33 containing the grating element 13 is to be packaged, a thickness and width of less than 2mm and 5mm, respectively, for the beam 11 is preferred. Where multiple optic fibre sections (33, 34, 35, 36, 37, 38, 39, 40) each containing the grating elements 13 are to be packaged, the width of the beam 11 should be large enough to support these multiple fibre sections.

Fig. 7C shows a top view of first beam 11 with optic fibre section 33 containing the grating element 13 embedded in surface 12 of the beam 11. Fibre section 33 is embedded into surface 12 by heat-cured epoxy or other epoxy 13. The fibre section 33 containing the grating element 13 is usually held in tension during the bonding process.

The ends 55, 66 connecting the first beam 11 and the second beam 22 can also be joined by laser welding, chemical bonding or mechanical bonding. For chemical bonding, epoxies can be used while for mechanical bonding, bolts and nuts are used.

The first beam 11 and second beam 22 each can have a polygonal cross-section, including a rectangular, square, circular or triangular. The first and second beams need not have the same polygonal cross-section. The first and second beams can be made of any suitable metal, glass or other materials. In the preferred embodiments, for example, beams 11 and 22 are made of Invar metal.

While this invention has been described above with respect to a specific embodiment, various changes in form and details may be made without departing from the scope of the invention. The beams and the member in this invention can have a variety of shapes and sizes. All such variations are encompassed in this invention.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

CLAIMS:

1. A temperature compensation package for a fibre grating element, comprising:
 - 5 a first member coupled to a second member at their respective ends, wherein said fibre grating element is disposed on the first member; and
a control means disposed between said first member and said second member, bending said first member and said second member into an arcuate shape, wherein the control means varies the curvature of said first member in
10 response to a variation in temperature, thereby compensating the thermal effect exerted on said fibre grating element by the variation of temperature.
2. A temperature compensation package according to claim 1, wherein said first member further comprises a flexible element, wherein said fibre grating
15 element is disposed on the flexible element.
3. A temperature compensation package according to claim 2, wherein said flexible element forms an arcuate shape when said control means is disposed between said first member and said second member.
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4. A temperature compensation package according to claim 2, wherein said flexible element is a flexible surface on said first member.
5. A temperature compensation package according to claim 4, wherein said
25 flexible element has a groove for receiving said fibre grating element.
6. A temperature compensation package according to claim 5, wherein said groove is V-shaped in cross-section.

7. A temperature compensation package according to claim 1, wherein said control means is an actuator for actively varying the strain applied to the fibre grating element.
- 5 8. A temperature compensation package according to claim 1, wherein said control means has a positive coefficient of thermal expansion.
9. A temperature compensation package according to claim 1, wherein said
10 control means compensating element has a negative coefficient of thermal expansion.
10. A temperature compensation package according to claim 1, wherein said first member is a first beam and said second member is a second beam, wherein
15 the first beam and second beam are connected at their respective ends.
11. A temperature compensation package according to claim 10, wherein the width of said first beam is more than or equal to the width of said second beam.
- 20 12. A temperature compensation package according to any one of claims 10-11, wherein the length of said first beam and the length of said second beam are each more than the length of said fibre grating element.
13. A temperature compensation package according to claim 10, wherein said
25 first beam is thin and flexible.
14. A temperature compensation package according to claim 10, wherein said second beam is thin and flexible.

15. A temperature compensation package according to claim 1, wherein said fibre grating element is disposed on said first member via a section of optic fibre containing said fibre grating element.
- 5 16. A temperature compensation package according claim 2, wherein said fibre grating element is disposed on said flexible element via a section of optic fibre containing said fibre grating element.
- 10 17. A temperature compensation package according to claim 16, wherein said optic fibre section is supported on said flexible element.
18. A temperature compensation package according to claim 17, wherein said optic fibre section is bonded to said flexible element.
- 15 19. A temperature compensation package according to claim 18, wherein said optic fibre section is embedded in said flexible element.