Fiber Bragg Gratings in Microstructured Optical Fibers for Stress Monitoring in Composite Laminates

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Fiber Bragg gratings (FBG) are widely recognized as one of today's most valuable optical fiber components in optical telecommunication, fiber laser technology and optical fiber sensing systems [1]. Measuring strain and structural damage are among the most important applications of FBG-based sensor technology. FBGs are commonly used to measure axial strain. However to monitor the structural health or assess damage of composite materials, it is also necessary to map the transversal stresses inside the material. For this purpose and as already reported, optical fibres with FBGs can be embedded in composite materials without compromising the structural integrity of the host material.
FBGs fabricated in microstructured optical fibers (MOF) have been recently reported in [2-4]. MOFs are a relatively new type of optical fiber that can be optimized for a large range of applications by tailoring the number, the size, the position and the geometry of the air holes that form the confining microstructure around a (sometimes doped) fiber core [5]. Owing to this design flexibility, FBG-based sensors in MOFs promise optimized and selective sensitivities via dedicated air hole geometries.
We study a FBG in a (highly birefringent) MOF to monitor transversal stress inside a composite material. In birefringent fibers a FBG yields 2 Bragg peak reflections, corresponding to both orthogonally polarized fundamental modes. The measurement of the transversal stress that is applied to the composite sample is encoded in the wavelength separation between the two FBG reflection peaks [6], which provides inherent temperature compensation. We present results from finite-element simulations of the fiber geometry. This allows both the mechanical and optical simulations to be performed in the same geometry and to couple their results. The transversal line load sensitivity is derived from phase modal birefringence calculations under different transversal load orientations on the MOF. Then we compare these results with experimental data of the bare fiber characterization.
Finally, we demonstrate stress sensing with the MOF embedded in a carbon fiber reinforced epoxy [7]. The response of the Bragg peak separation to a transversal stress in the composite sample was highly linear (see Figure 1). In addition, the temperature response was negligible in comparison with FBGs in conventional birefringent fibers (see Figure 2) [8].

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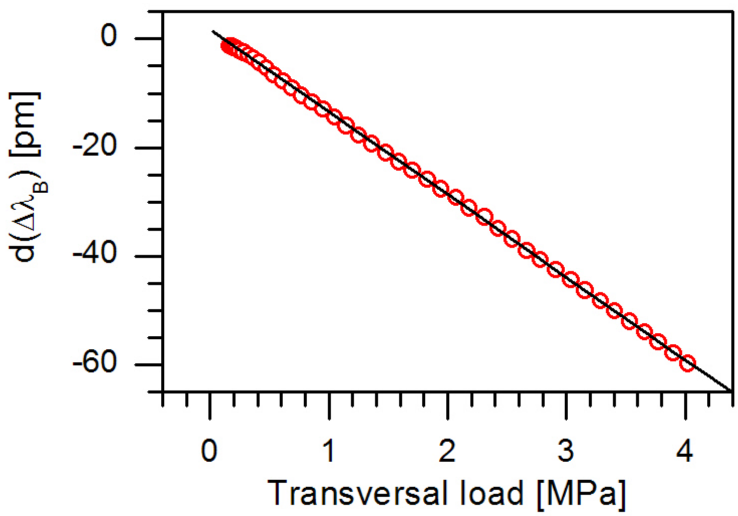

Figure 1: Measured Bragg peak wavelength separation versus applied transversal load. The straight line is a linear fit of the data points [7].

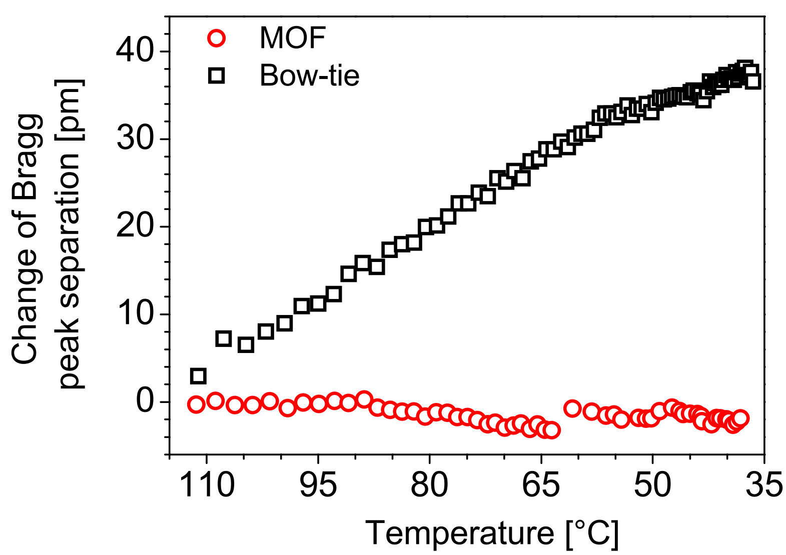

Figure 2: Measured change of the Bragg peak separation for an FBG in the birefringent MOF and in a bow tie fiber with temperature [8]. The Bragg peak separation is almost insensitive for temperature changes.