Sensitivity to deformation of an FBG sensor

The Fiber Bragg Grating sensor (FBG) allows to measure the deformation because it produces a wavelength response proportional to the variation of its grating pitch Λ induced by the deformation itself.

The wavelength λ_B reflected by a Bragg grating is in fact expressed by the relation

$$\lambda_B = 2n_{eff}\,\Lambda$$

where n_{eff} is the effective refraction index of the grating.

A variation L of the grating length induces then a variation of Λ and then of λ.

The deformation ε can therefore be calculated as:

$$\epsilon = \frac{\Delta L}{L} = \frac{\Delta \Lambda}{\Lambda} = \frac{\Delta \lambda_B}{(1-p_e)\lambda_B}$$

where p_e is a coefficient accounting the elasto-optic effects on the refraction index of the sensor and is

$$p_e \approx 0{,}22$$

It follows that the deformation causing a variation of 1 pm in the wavelength reflected by a sensor with, for example, λ_B = 1530.5 nm, is 0,837 $\mu\varepsilon$.

The measurement sensitivity in wavelength, expressed in pm/$\mu\varepsilon$ is then about

$$s_\lambda = 1{,}19 \text{ pm}/\mu\varepsilon$$

Thermal sensitivity of an FBG sensor

Due to the effect of temperature, the Bragg lambda λ_B undergoes a change $\Delta\lambda_B$ as a function of temperature change ΔT, expressed by the relationship

$$\Delta\lambda_B = 2\Lambda(\alpha n_{eff}+\eta)\Delta T$$

where α and η represent the coefficient of thermal expansion and the thermo-optic coefficient of the grating material, respectively:

$$\alpha=\frac{1}{\Lambda}\frac{\Delta\Lambda}{\Delta T}$$

$$\eta=\frac{\delta n_{eff}}{\delta T}$$

The temperature change (ΔT) results in a change in the refractive index of the core and cladding by an amount determined by the value of η (whose typical value is 8.3e-6 $°C^{-1}$), which ultimately causes the Bragg wavelength shift.
Fiber expansion can also contribute to the Bragg wavelength shift. However, the latter effect can generally be ignored because αn_{eff} (typically 0.55e-6*1.4725 = 0.809e-6 $°C^{-1}$) is an order of magnitude less than η.