Sub-metre spatial resolution temperature compensated distributed strain sensor

Mohammad Belal and Trevor Newson
Optoelectronics Research Centre, Southampton University

Abstract text: We propose and demonstrate a scheme which utilizes the temperature dependence of spontaneous Raman scattering to provide temperature compensation for a sub-metre spatial resolution Brillouin frequency based strain sensor. Temperature compensated strain sensor measurements have been demonstrated with a strain resolution of 94 με and a spatial resolution of 10 cms.

This paper describes the combination of Brillouin frequency based BOCDA technique [1] with an independent measurement of temperature, based on the determination of the intensity of the anti-Stokes Raman scattering (R-OTDR) with very much higher spatial resolution than previously reported [2], in order to produce a fully temperature compensated strain sensor with high spatial resolution.

In order to discriminate temperature and strain, the change in Brillouin frequency shift from BOCDA and intensity from R-OTDR can be expressed in matrix form, which on solving allows for the temperature compensated strain to be ascertained, as given by equation 2.

$$\begin{bmatrix} \Delta \nu_b \\ \Delta I_{R} \end{bmatrix} = \begin{bmatrix} C_{\nu_B} & C_{I_R} \\ C_{\nu_B} & C_{I_R} \end{bmatrix} \begin{bmatrix} \Delta \nu_b \\ \Delta I_{R} \end{bmatrix}$$

(1)

$$b(\Delta \nu) = \frac{C_{\nu_B}^{2} \Delta \nu_{B}^{2} + C_{I_{R}}^{2} \Delta I_{R}^{2}}{C_{\nu_B}^{2} C_{I_{R}}^{2}}$$

(2)

where $C_{\nu_B}^{2}$ and $C_{I_{R}}^{2}$ are the coefficients for the Brillouin frequency shift due to strain and temperature respectively and $C_{I_{R}}$ is the coefficient for the Raman anti-Stokes intensity change with temperature. The coefficient for the Raman anti-Stokes intensity is insensitive to strain, hence $C_{\nu_B} = 0$. $\Delta \nu_{B}$ and $\Delta I_{R}$ are the Brillouin frequency shift and the Raman anti-Stokes intensity change respectively while $\Delta \nu_{B}$ and $\Delta I_{R}$ are the RMS errors on the Brillouin frequency and Raman anti-Stokes intensity measurements.

References
