Sub-metre spatial resolution temperature compensated distributed strain sensor

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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 94uε and a spatial resolution of 10cms.

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.

$$\begin{bmatrix} \Delta\nu_B \\ \Delta I_{R_{A.S}} \end{bmatrix} = \begin{bmatrix} C_{B\nu}^{\varepsilon} & C_{B\nu}^{T} \\ C_{RI}^{\varepsilon} & C_{RI}^{T} \end{bmatrix} \begin{bmatrix} \Delta\varepsilon \\ \Delta T \end{bmatrix} \quad (1)$$

$$|\delta(\Delta\varepsilon)| = \frac{|C_{RI}^{T}||\delta\Delta\nu_B| + |C_{B\nu}^{T}||\delta\Delta I_{R_{A.S}}|}{|C_{B\nu}^{\varepsilon}C_{RI}^{T}|} \quad (2)$$

where $C_{B\nu}^{\varepsilon}$ and $C_{B\nu}^{T}$ are the coefficients for the Brillouin frequency shift due to strain and temperature respectively and C_{RI}^{T} 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_{RI}^{ε} = 0. $\Delta\nu_B$ and $\Delta I_{R_{A.S}}$ are the Brillouin frequency shift and the Raman anti-Stokes intensity change respectively while $\delta\Delta\nu_B$ and $\delta\Delta I_{R_{AS}}$ are the RMS errors on the Brillouin frequency and Raman anti-Stokes intensity measurements.

References

[1] K. Y. Song, Z. He, and K. Hotate, ‘‘Distributed strain measurement with millimeter-order spatial resolution based on Brillouin optical correlation domain analysis’’, Opt. Lett. **31**, 2526-2528 (2006)

[2] M N Alahbabi, Y T Cho and T P Newson, ‘‘Simultaneous temperature and strain measurement with combined spontaneous Raman and Brillouin scattering’’, Opt. Lett. **30 (11)** 1276-1278 (2005)