AN OPTICAL FIBRE CABLE FOR DISTRIBUTED PRESSURE SENSING WITH HIGH RESOLUTION AND SENSITIVITY

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In this work, we present an optical fibre cable for distributed pressure sensing employing standard single-mode fibres. The cable can be interrogated with a distributed strain sensing interrogator, either based on Rayleigh or Brillouin scattering. By using an optical frequency domain reflectometer with 1 $\mu\varepsilon$ of strain resolution on a cable prototype, we found that the spatial resolution is approx. 8.5 cm, and the pressure resolution and accuracy are approximately 5 Pa and 10 hPa, respectively.
Keywords: Optical fibre cable, distributed pressure measurements.

1. Cable structure and working mechanism

The measurement of pressure at high spatial resolution is of paramount importance in many different fields, including industrial and environmental applications [1]. The distributed pressure sensing (DPS) cable proposed here aims at addressing these applications.
The structure of the cable is shown in Figure 1 (a-c). The elements that constitute the cable are: (i) two thick D-shaped rubber profiles (① in Fig. 1(a)), for protection and pressure-transfer purpose; (ii) four compliant rubber triangular profiles (② in Fig. 1(a)) cemented to the aforementioned D-shaped rubber; (iii) a fabric strip at the neutral axis of the cable (③ in Fig. 1(a)), glued to the triangular profiles. The strip is impregnated with liquid rubber and embeds the fibre; (iv) the fibre embedded in the strip (④ in Fig. 1(a)) and deployed according to a dense meandering path (Fig. 1 (b) and (c)).
The cable works as follows: any positive external pressure squeezes the D-shaped profiles inducing a pulling force that extends the inner strip transversely.

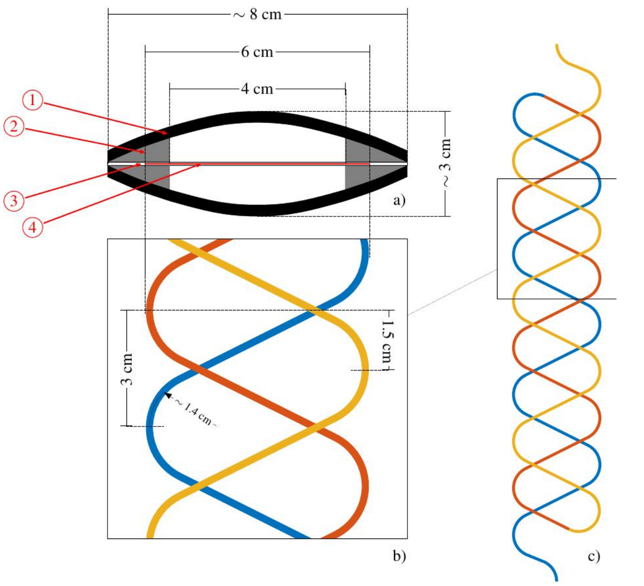

Fig. 1 (a) The cable cross-section with dimensions and constitutive elements. (b) Magnified view of the fibres meandering path. (c) Meandering path of the embedded fibre.

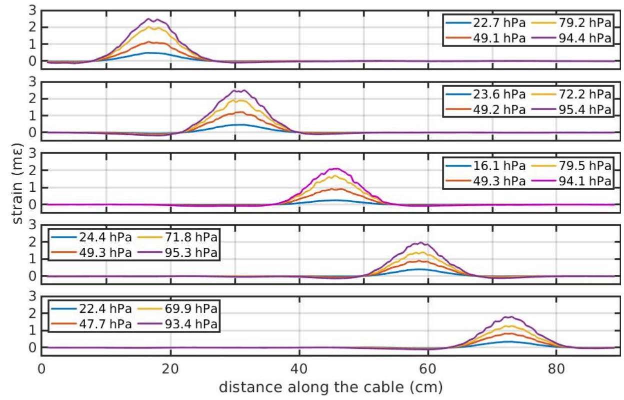

Fig. 2 Rayleigh spectral shifts for increasing pressure applied at five different positions along the cable.

The embedded fibre gets stretched as well, and the component of the pulling force along the fibre direction determines a strain that can be measured by any distributed strain sensing (DSS) technique. The transducer working mechanism is similar to that proposed in [2], here implemented in a distributed way.

2. Performance assessment

A prototype of the cable, 1-metre long, has been built and characterized to assess its performance. The characterization has been carried out using a commercial DSS device, the OBR 4400 by Luna Innovation Inc. ©, which exploits the Optical Frequency Domain Reflectometry (OFDR) [3], with a spatial and strain resolution of 2 cm and 1 $\mu\varepsilon$, respectively. Some examples of the measured pressure-induced strain are plotted in Fig. 2. Ultimately, the cable shows a spatial resolution, pressure resolution, and accuracy (determined as the maximum absolute error of the estimated pressure) of approximately 8.5 cm, 5 Pa, and 10 hPa, respectively.

References

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