A FIBRE-OPTIC TEMPERATURE-DISTRIBUTION SENSOR

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Introduction: The development of all-optical fibre-sensors for monitoring a wide range of physical parameters is currently of considerably interest. It is attractive to consider an optical measurement of temperature, pressure, strain and vibration at a remote location situated in a hazardous environment or which suffers from severe electrical interference. In many cases it is desirable to determine the spatial distribution of the sensed quantity. For example, in certain applications it is necessary to monitor the variation of temperature within a machine, pipe or oven, or within a reservoir.

In the present contribution, we propose and demonstrate the operation of a novel distributed temperature sensor in which optical time-domain reflectometry is used to determine temperature-induced changes in backscatter signal at any point along a specially-designed fibre. The choice of fibre is important since in this application strong changes in scatter return with temperature are an advantage. We have chosen in the first instance a liquid-core fibre, since it is known that liquids exhibit large variations in both refractive index and Rayleigh scatter coefficient with temperature.

Experiment and results: High-resolution backscatter measurements were performed on fibres consisting of 200μm-bore silica capillary tubing filled with hexachlorobuta-1,3- diene [1].

Typical backscatter waveforms are shown in Fig. 1 for several different temperature distributions. In each case, Sections 1 and 3 were held at 20°C while the temperature of the central 15m section, 2, was varied as indicated. It is clear that the scattered power returning from section 2 is directly related to the local temperature. The observed sensitivity results entirely from the increase of Rayleigh scatter coefficient with increasing temperature. A concurrent change in numerical aperture produces a spurious effect which has been eliminated by suitable design of the receiving optics.

Measurements were made over the range 5-80°C, although the sensor can potentially operate from 0-200°C. The resulting sensitivity curve is shown (inset) in the form of the power-ratio at the temperature transitions as a function of the temperature-difference. The sensitivity is linear and has a value 0.018 $dB.K^{-1}$ over the range. The spatial resolution is limited by the pulse width of the laser, the bandwidth of the receiver and the dispersion of the fibre. Typically we have obtained a resolution of 1m over at least 100m, giving a minimum of 100 resolvable temperature measurements. By suitable choice of fibre materials it is possible to envisage shifting the sensor range to high temperatures, or to cryogenic temperatures.

Conclusions: The distributed temperature sensor described above can be seen as the first of a class of sensors which use the backscatter technique to sense spatially-distributed changes in scattering-loss, bending loss, refractive index or absorption. These changes can be induced by temperature, pressure, strain or vibration.

Reference

1. D. N. Payne and W. A. Gambling, Electronics Letters, 8, 1972 pp. 374-376

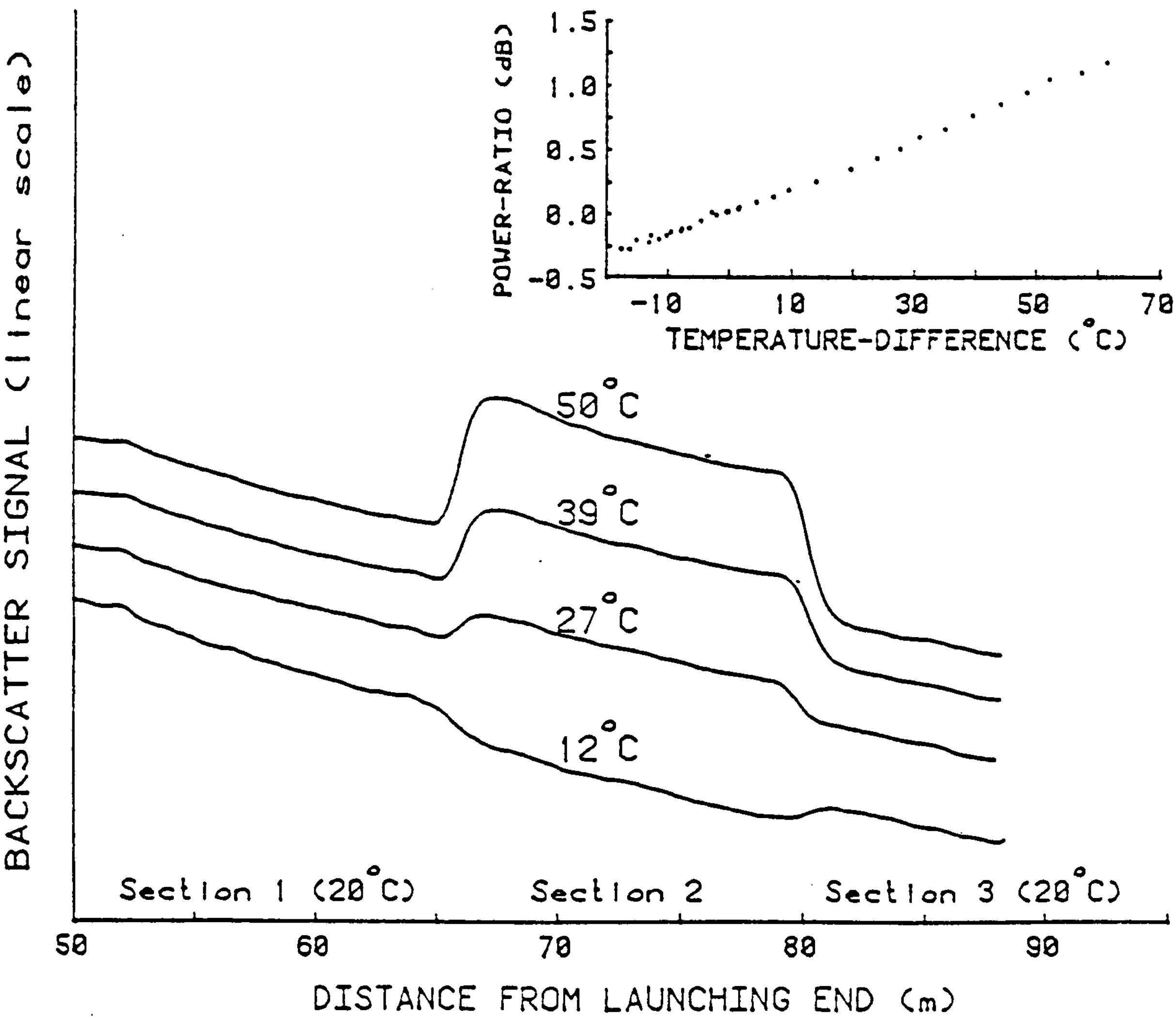

Fig. 1