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Distributed Temperature Sensing using the Landau-Placzek Ratio

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Abstract: We report a commercially viable high spatial resolution, long range optical fibre distributed temperature sensor based on Brillouin scattering exploiting a low cost detection system. A spatial resolution of 3.5 metres with a Brillouin temperature resolution of 0.9°C at a range of 16km has been achieved.

Introduction: Optical fibre distributed temperature sensors (DTS) is a rapidly expanding field which has applications as diverse as fire detection in underground storage tanks to the monitoring the temperature profile of power cables. These applications rely on the immunity of fibre optic sensors to electro-magnetic interference and the ability of fibre sensors to be operated in environments where electrical signals are hazardous. The use of optical fibre sensors for temperature sensing is an elegant way of monitoring quasi-simultaneously thousands of points without knowing the optimum positioning for discrete sensors. DTS systems rely on launching a short pulse of light into the sensing fibre and investigating the backscattered light. Current commercially available temperature sensors function by detecting the Raman backscattered light, the intensity of which provides information on the temperature profile of the fibre under test. This paper demonstrates recent advances in distributed temperature sensing based on Brillouin scattering.

Experiment: The experiment consists of two basic components; a laser source to generate the backscattered signal and a low cost detection system which comprises an in-fibre Mach-Zehnder interferometer and a sensitive InGaAs APD connected to a computer based averaging system. It is the relative low cost of these two components which has enabled the Brillouin based temperature sensor to be constructed for commercially exploitation.

Q-switched fibre laser: Recent advances in the field of optical fibre Bragg gratings has made it possible to produce a Q-switched Erbium doped fibre laser source which satisfies the properties required for Brillouin distributed sensing [1]. The laser produces high power (10W), short duration (35ns) pulses at a repetition rate of 1kHz. The laser wavelength is 1532nm, which is in the low-loss window of single-mode silica fibre, a necessary criterion for a long range sensor. The linewidth of the laser is determined by the use of an in-fibre Bragg grating as one mirror of the laser cavity and is measured to be 2GHz using a Fabry-Perot interferometer. A narrow linewidth source is required in order to spectrally resolve the Rayleigh and Brillouin backscattered light which are separated by a frequency of 10GHz.

Mach-Zehnder Interferometer: The detection systems used in recent distributed Brillouin temperature sensors operate on heterodyne detection or the use of expensive, high loss bulk Fabry-Perot interferometers. In this paper we report on the use of a double pass configured in-fibre Mach-Zehnder interferometer (Figure 1) consisting of two 3dB couplers to spectrally resolve the backscattered Brillouin signal [2]. This double pass device, provides in excess of 26dB extinction of the Rayleigh signal from the Brillouin and is stabilised using a Peltier heat pump on one arm of the device. This provides a control of the path imbalance in the interferometer. The feedback for the control is provided from a 5% tap in the Rayleigh arm which the controller aims to maximise. In maximising this Rayleigh, the counter-propagating Brillouin signal is then

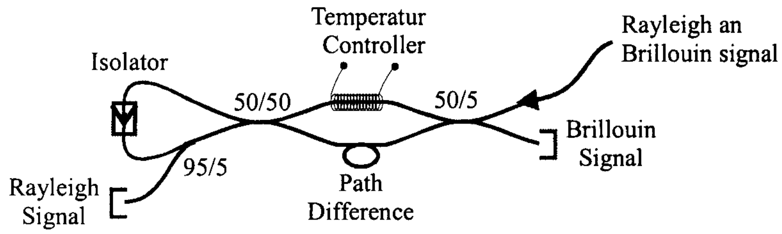

Figure 1 - Mach-Zehnder Interferometer

maximised and can be detected at the output of the filter. The control circuit is used to match the peak of the transfer function of the Mach-Zehnder to the wavelength of the laser generating the backscattered light. The laser wavelength drifts slowly with time because of the dependence of the grating wavelength on temperature (1.25GHz/°C @ 1.53μm). The time response of the control circuit is selected to track this temperature shift.

Results: The results obtained are shown in figure 2, this plot shows the Landau-Placzek ratio, that is the ratio of the Brillouin signal to the Rayleigh signal, for a section of the fibre which has the temperature profile of 80°C, 0°C and 40°C in equal 100metre sections. These results are taken at a distance of 16km down the sensing fibre. The RMS temperature resolution of the Brillouin signal was measured to be 0.9°C with a spatial resolution of 3.5metres. The ratio of the Rayleigh and Brillouin is taken to remove the dependence of the signal of localised splice/bend losses (Figure 2). A higher temperature resolution of 1.4°C was measured due to the presence of coherent Rayleigh noise. A method of reducing this by scanning the laser over a number of nanometres or using a broadband source to take the Rayleigh measurement is currently being implemented and a 0.9°C temperature resolution on the Landau-Placzek ratio is deemed possible. We believe the reduced cost of the detection system demonstrated here could significantly improve the attractiveness of Brillouin scattering for temperature sensing.

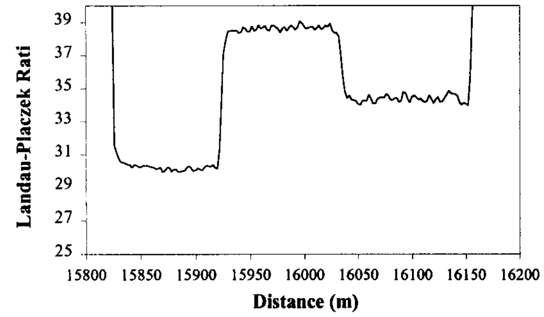

Figure 2 – Landau-Placzek Ratio

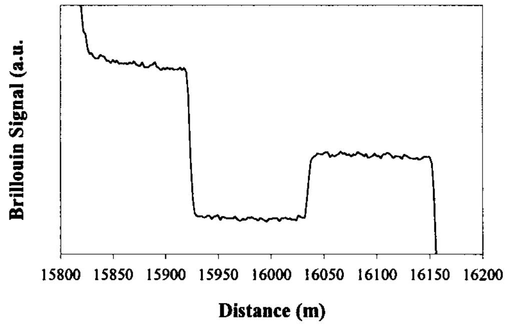

Figure 3 – Brillouin Backscattered Signal

References:

[1] G.P.Lees, M.J.Cole and T.P.Newson: 'A Narrow linewidth Q-switched Erbium doped fibre laser', *Electronics Letters*, Vol.32, No.14, pp.1299-1300, (1996)

[2] K. De Souza, G.P.Lees, P.C.Wait and T.P.Newson: 'Diode-pumped Landau-Placzek based Distributed Temperature Sensor utilising an all-fibre Mach-Zehnder Interferometer', *Electronics Letters*, Vol.32, No.23, pp.2174-2175, (1996)

[3] G.P.Lees, P.C.Wait, M.J.Cole and T.P.Newson: 'Advances in Optical Fibre Distributed Temperature Sensing using the Landau-Placzek ratio', *IEEE Photonics Technology Letters,* Vol.10, No.1, pp.126-128, (1998)