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Spontaneous Brillouin-based distributed temperature fibre sensor with 35cm spatial resolution

Although distributed optical fibre temperature sensors based on Brillouin scattering have been researched for a number of years [1,2], measurement accuracy has been limited to a minimum spatial resolution of a few metres. However, certain applications require a sub-metre spatial resolution accuracy and there has been much interest as to whether the Brillouin linewidth ultimately limits the spatial resolution that can be achieved. We present a demonstration of a spontaneous Brillouin-based distributed temperature sensor with a spatial resolution of 35cm.

There are two main components in the system in addition to the sensing fibre; a laser source to generate the Brillouin backscattered signal and a low cost filtering and detection system which comprises of an all-fibre Mach-Zehnder interferometer and a sensitive InGaAs detector connected to a computer based averaging system. There is a need to generate a high peak power within the short pulse, to maximise the backscattered signal. The signal pulse was generated from a narrow linewidth CW distributed feedback (DFB) laser diode with an output power of 2.5mW externally modulated by a fast $LiNbO_3$ electro-optic modulator (EOM). This signal pulse was then amplified using an Erbium-doped fibre amplifier (EDFA) and the residual ASE noise was filtered by an in-fibre Bragg grating. The reflected signal was then amplified using another EDFA to overcome the loss of the acousto-optic modulator (AOM) which served to gate the pulse and filter the ASE generated by the second EDFA. The resultant signal pulse had a peak power of 5W, pulse width of 3.5ns. The signal was then launched into the sensing fibre through a circulator.

The detection systems used in recent distributed Brillouin temperature sensors operated on heterodyne detection [1] or the use of expensive, high loss bulk Fabry-Perot interferometers [2,3]. In this experiment, a double pass configured in-fibre Mach-Zehnder interferometer was used to separate spectrally the Brillouin signal from the Rayleigh signal. This low-loss interferometer provided in excess of 26dB extinction of the Rayleigh signal from the Brillouin and was locked using a peltier cooler in thermal contact with one arm of the interferometer. The sensing fibre was 1km in total, consisting of three sections of conventional single-mode fibre spliced together with lengths of 600m, 200m and 200m respectively. The second drum was heated to 67°C, an increase of 44°C from the room temperature of 23°C, and the other two drums were at room temperature.

The results show that there is a clear rise of the Brillouin signal in the heated section. The signal at the end of the sensing fibre is well above the noise floor, indicating that measurements may be made for sensing lengths exceeding 1km. In order to take absolute measurements independent of fibre attenuation and localised splice/bend losses, the Brillouin signal has to be referenced to the Rayleigh backscattered signal which is independent of temperature fluctuations. To minimise coherent effects, the Rayleigh signal was obtained by using a broadband pulsed source in place of the DFB laser diode. The ratio of the Brillouin and Rayleigh signals is known as the Landau-Placzek ratio and provides a temperature dependent signal which is corrected for splice/bend losses and fibre attenuation. From the calculation of r.m.s. noise on the Landau-Placzek ratio, the temperature resolution of the trace corresponded to 4.3°C. By measuring the rise time at the slope between signals at different temperatures, the spatial resolution was determined to be 35cms.

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