Brillouin Based OTDR With Measurement Range of 85 km Using Combined EDFA and Raman Amplification

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We report the enhanced performance of an 85 km single-ended distributed Brillouin based temperature sensor using an EDFA and Raman amplification. A temperature resolution of 3°C and spatial resolution of 20 m was achieved.

There has been a considerable amount of research into increasing the measurement range of Brillouin based distributed temperature sensors which rely on the temperature dependency of the intensity of the spontaneous Brillouin signal. The demand for this kind of sensor comes mainly from applications involving temperature profiling of energy cables [1]. Previously, we have demonstrated the use of Raman amplification at the midpoint of the sensing fibre to enhance the measurement range [2]. However, it was not a fully single-ended system. In this paper, we have investigated a remotely pumped EDFA combined with Raman amplification. The same pump was used for both remotely pumping the EDFA and to provide Raman gain. We have demonstrated a temperature resolution of less than 3 °C over a sensing range up to 85 km.

The experimental setup is shown in figure 1. The CW Raman pump at 1480 nm, with optical bandwidth of 0.5 nm and pump power of 730 mW (below the calculated SBS threshold of 2.6 W), co-propagated in the sensing fibre with the 200 ns probe pulse, peak power of 40 mW at 1533 nm. In the first 48 km, both the probe pulse and backscattered signals were amplified by the CW pump via Raman amplification. The Raman gain coefficient was determined to be 1.0 x 10^{-14} m/W. The EDFA provided further amplification at 48 km. The 1480 nm pump power had fallen to 40 mW and was used to pump the 2 m section of EDFA (concentration of 100 ppm). The backscattered signals were averaged 2^{20} times.

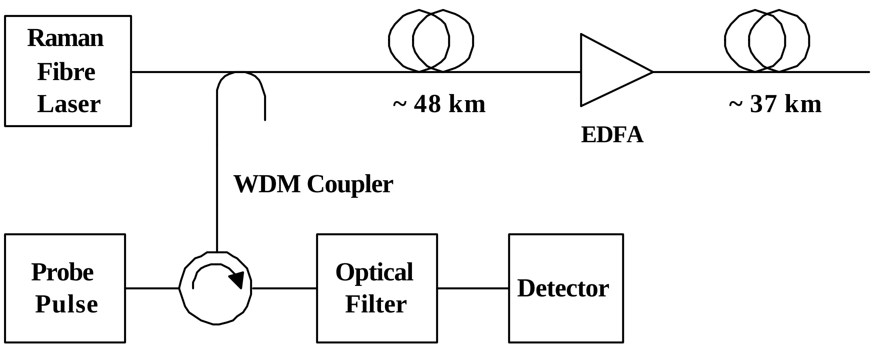

Fig. 1. Experimental setup.

Fig. 2. Intensity profile of the spontaneous Brillouin backscattered signals, (a) with amplification and (b) without amplification.

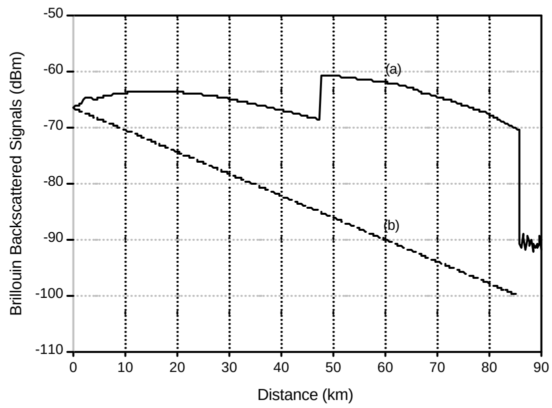

Figure 2 shows the backscattered Brillouin trace over the entire sensing fibre with (a) the combined Raman and Erbium amplification and (b) without amplification (simulated results). The maximum range without amplification was limited to approximately 60 km. Beyond this value, the signal level was below the noise floor of the detector of –90 dBm.

Fig. 3. The temperature resolution profile. Inset, the enlarged view of Brillouin signal at 76 km.

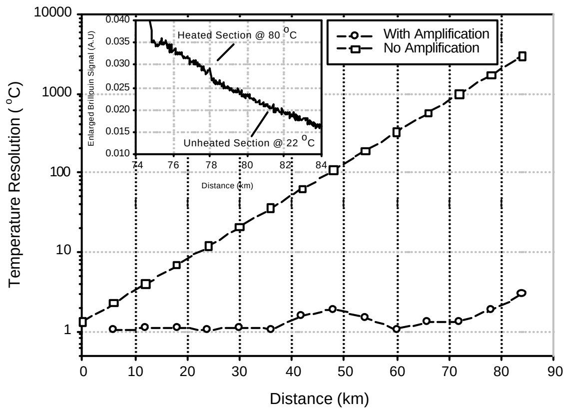

Figure 3 shows the temperature error measured in steps of 6 km over the whole length of the sensing fibre. With amplification, the temperature resolution increased from 1°C at 6 km to 3°C at 84 km, (circles). The temperature resolution without amplification was estimated based on a signal decay of 0.4 dB/km corresponding to the two-way loss (squares) and an estimate 1°C resolution at the front end. It can be seen that without optical amplification, the temperature resolution would have deteriorated from 1°C at approximately to 3000°C at 84 km. The rise in the signal level observed in the inset of figure 3 corresponded to the heated section at 80 °C at a distance of 76 km. The other spools of fibre were kept at room temperature of 22 °C.

In conclusion, an 85 km single-ended distributed temperature sensor employing both EDFA and Raman amplification and temperature resolution of less than 3°C has been demonstrated.

References

[1] F.H. de Wild, P. Schmetz, " The Applications of Optical Sensors for Temperature, Mechanical Stress and Moisture in Energy Cables in The Netherlands", Technical Digest of Optical Fibre Sensors 14, pp 820 (Venice, Italy, 2001).

[2] Y.T. Cho, M. Alahbabi, M.J. Gunning and T.P. Newson, "Enhanced performance of long range Brillouin intensity based temperature sensors using remote Raman amplification", Technical Digest of Optical Fibre Sensors 16, pp. 392 (Nara, Japan, 2003).