OFS 2002 (accepted)

3338

Brillouin-Based Distributed Fibre Temperature Sensor at 1.53 μm Using Raman Amplification

Y.T. Cho and T.P. Newson

Optoelectronics Research Centre, University of Southampton
Southampton SO17 1BJ, United Kingdom
Tel: +44 02380 593836 Fax: +44 02380 593835
Email: YTC@ORC.SOTON.AC.UK

ABSTRACT

This paper describes the first demonstration of increasing the dynamic range of Brillouin-based distributed temperature sensor at 1533 nm using Raman amplification provided by a 1450 nm pump source.

Brillouin-Based Distributed Fibre Temperature Sensor at 1.53 μm Using Raman Amplification

Y.T. Cho and T.P. Newson

Optoelectronics Research Centre, University of Southampton
Southampton SO17 1BJ, United Kingdom
Tel: +44 02380 593836 Fax: +44 02380 593835
Email: YTC@ORC.SOTON.AC.UK

1. INTRODUCTION

The Brillouin-based distributed temperature fibre sensors (BDTS) [1,2] using conventional single mode fibres have been researched for many years. Significant interests are directed towards developing longer range and higher spatial resolution distributed fibre sensors. Applications of such sensors include real time thermal rating of high power cables [3] and temperature profiling [4].

In direct detection, the intensity of the spontaneous Brillouin backscatter was measured as it exhibits temperature sensitivity of 0.3 %/°C. However, the sensing range is limited by the detector's sensitivity and the power of pulsed light that can be launched into the system before nonlinear scattering occurs. Optical preamplification of Brillouin signal have been reported in [5] to increase the dynamic range of BDTS. In addition, Raman amplification has been used in long range OTDR at 1650 nm [6].

In this paper, we propose an alternative technique of increasing the sensing range of the BDTS by using Raman amplification of the Brillouin backscatter signal. This method operates with a continuous-wave (CW) pump at 1450 nm which amplifies the probe pulse thereby increasing its energy further down the sensing fibre.

2. EXPERIMENT

The experimental configuration is illustrated in Figure 1. A narrowband Q-switch fibre laser (1.6 GHz) at 1533 nm was used to generate the Brillouin backscatter signal. The Rayleigh signal was obtained using a broadband Q-switch fibre laser (300 GHz) to minimise the effects of coherent Rayleigh noise. The pulses with powers of approximately 200 mW and pulsewidth of 60 ns were launched into the sensing fibre. The CW Raman pump at 1450 nm with output power of 100 mW was passed through a wavelength division multiplexer coupler (WDM) together with the signal pulse at 1533 nm. As the pump propagated down the sensing fibre, the signal pulse depleted the pump.

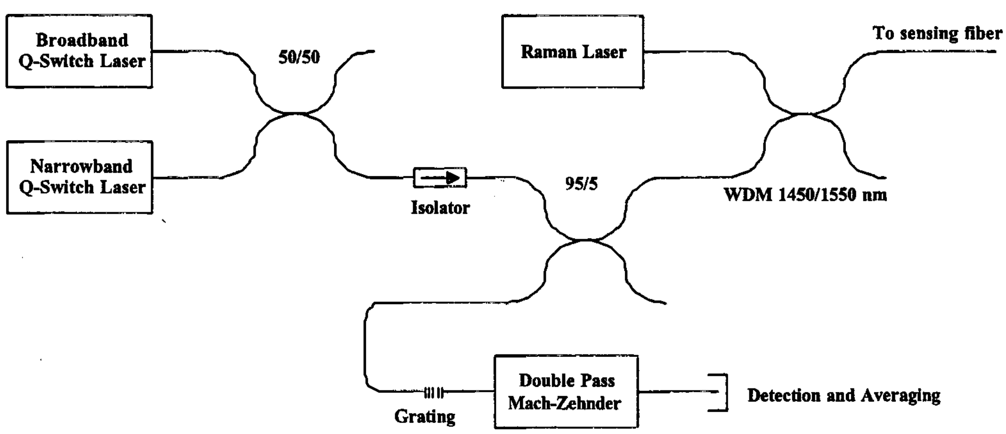

Figure 1: Experimental configuration of distributed temperature sensor. Either a broadband or narrowband source is used in collection of data.

A fibre grating (Reflectivity = 99 %, $\Delta\lambda$ = 0.12 nm, λ_c = 1532.85 nm) was used in conjunction with the double pass fibre Mach-Zehnder interferometer (DPMZ) to separate the Rayleigh signal from the Brillouin. Tuning this combination of grating and DPMZ allowed either Rayleigh or Brillouin signal to be detected and provided average rejection in excess of 33 dB. Both the grating and the DPMZ were thermally tuned and controlled using a peltier cooler and temperature controller. The DPMZ has been previously described in detail [7]. The Brillouin signal was then collected using the InGaAs photodetector with a bandwidth of 3MHz.

3. RESULTS

The sensing fibre consisted of six sections of lengths 19 km, 5 km and 2.8 km, 4 km, 0.2 km and 4 km. The third and fifth section was placed in the oven and heated to approximately 80°C. The other drums of the fibres were kept at room temperature 21°C. It can be seen from the plot that there is an increase in intensity in the heated section. Figure 3 shows the plot of amplified Brillouin trace with Raman pump power ranging from 0 mW to 200 mW. It can be seen that there is an increase in the intensity levels with increasing pump power. With pump power of 200 mW, the intensity of the Brillouin signal was increased fourfold at approximately 24 km. In addition, the dynamic range was increased by 8.43 dB at the far end of the sensing fibre.

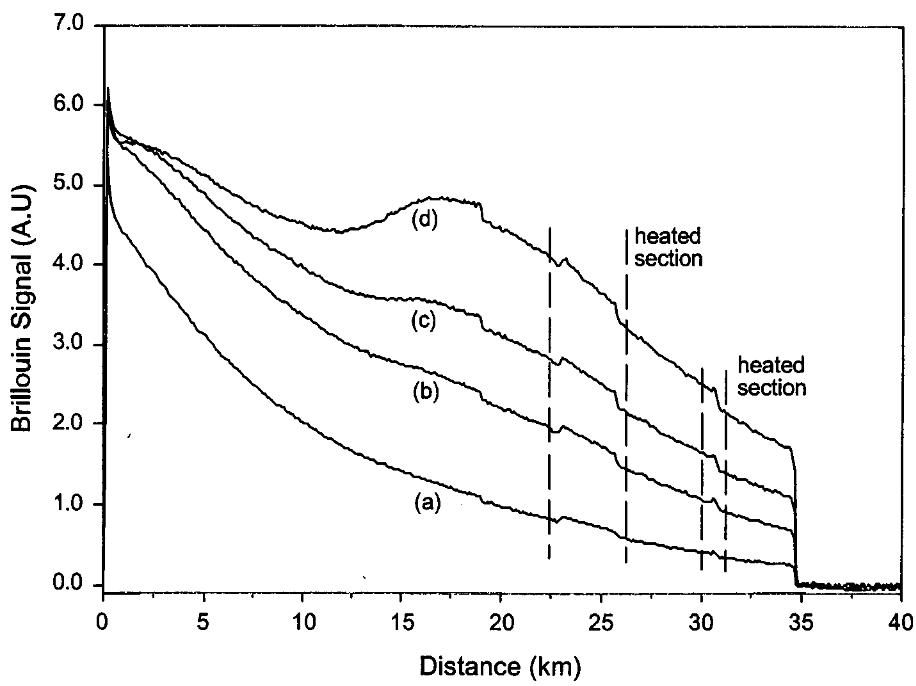

Figure 3: Results of amplified Brillouin signal with different pump power. The curves of (a), (b), (c) and (d) shows pump power at 0 mW, 100 mW, 150 mW and 200 mW respectively.

4. CONCLUSION

We have demonstrated a new technique of increasing the dynamic range of the Brillouin-based sensor using Raman amplification. Using this method, the experimental results illustrate an increase in the dynamic range of approximately 8.43dB at the end of the sensing fibre using Raman amplification. This increase in signal level of 8.43 dB at the far end of fibre equates to a range of increase of approximately 20 km taking the fibre attenuation to be 0.2 dB/km, as there was little evidence of a significant increase in noise level. Further enhancement is anticipated using the Raman pump in pulsed operation combined with improved filtering of unwanted frequencies in the Raman pump laser. The usual normalisation of the Brillouin trace [8] can be achieved by dividing it by the Rayleigh trace to compensate for splice losses etc, as the Rayleigh signal experience the same gain profile. We believe Raman amplification will become an important tool to improve the performance of a wide range of distributed fibre optic sensors.

5. REFERENCES

[1] T. Kurashima, T. Horiguchi, H. Izumita, S. Furukawa and Y. Koyamada, " Brillouin optical-fiber time domain reflectometry," *IEICE Trans. Commun.*, Vol. E76-B, No. 4, pp. 382-389, 1993.

[2] V. Lecoeuche, M. W. Hathaway, D. J. Webb, C. N. Pannell and D. A. Jackson, "20-km Distributed Temperature Sensor Based On Spontaneous Brillouin Scattering," *IEEE Photonics Tech. Lett.*, pp. 1367-1369. October 2000.

[3] G. M. Nokes, "Optimising power transmission and distribution networks using optical fiber distributed temperature sensing systems," *Power Eng J.*, pp. 291-296. Dec 1999.

[4] A.H. Hartog ,"Distributed temperature sensing in solid core fibers," *Electron.Lett.*, Vol. 21, pp. 1061, 1985.

[5] K.D. Souza and T.P. Newson, "Brillouin-based fiber optic distributed temperature sensor with optical preamplification," *Optics Lett.*, Vol. 25, No. 18, pp. 1331-1333. September 15, 2000.

[6] H.H. Kee. G.P. Lees and T.P. Newson, " An extended range OTDR system at 1.65 μm based on delayed Raman amplification," *Optics Lett.*, Vol. 23, No. 5, pp. 349-351, March 1998.

[7] K.D. Souza. G.P. Lees, P.C Wait and T.P. Newson, "Double-pass configured fiber Mach-Zehnder interferometric optical filter for distributed fiber sensing," *Electronics Lett.*, Vol. 33, No. 24, pp. 2148-2149, 1997.

[8] P.C Wait and T.P. Newson, " Landau-Placzek Ratio Applied to Distributed Fibre Sensing," *Optics Communications*, Vol. 122, No. 4-6, pp. 141-146, 1996.