A Raman intensity sensor induced by the Rayleigh scattering in a ring configuration

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ABSTRACT

In this work, a laser sensor that uses the multipath interference produced inside a ring cavity to measure the power loss induced by a moving taper intensity sensor is described. The laser is created due to the virtual distributed mirror formed by the Rayleigh scattering produced in a dispersion compensating fibre when pumped by a Raman laser. Two laser peaks were formed, one of them is obtained by the Raman gain (1555 nm) inside the ring and the second is created by the combination of the Raman gain and the Rayleigh scattering (1565 nm). A taper sensor is used as displacement sensor and with the increases of losses the second laser peak amplitude is reduced. In the process the first peak is maintained constant and can be used as reference level.

Keywords: Raman scattering, cooperative Rayleigh scattering, optical fibre sensor.

1. INTRODUCTION

Rayleigh scattering (RS) is an unavoidable property of light transmission in optical fibres and is mainly generated due to density variations of the core material. In most practical setups, the amount of RS generated is quasi negligible. However, in Raman configurations the pump power (P_p) has enough power to intensify this phenomenon. So it is very important to control the quantity of RS produced because those reflections could be amplified and added to the signal. Nevertheless, it can become even more destructive when the RS is itself reflected leading to double Rayleigh scattering (DRS). The signal and the RS could experience several reflections leading to multiple path interference (MPI). As the MPI is no longer correlated to the signal it is added to it as a noise source degrading the system performance [1]. The limitations of this mechanism have been extensively studied [1-3]. Although this occurrence is always avoided in signal transmission it may be cooperative for other application such as: laser generation [4-6] or interrogation techniques [7].

In this paper, it is presented an innovative intensity displacement sensor based on a virtual distributed mirror. The sensor uses the MPI produced by Rayleigh scattering within a ring cavity to measure attenuation produced by a taper sensor. Its response was characterized for loss variations of up to 1.5 dB.

2. EXPERIMENTAL RESULTS

The sensor set-up consists in a ring configuration as shown in figure 1. The high pump Raman laser emits a maximum of 5 W at 1455 nm and injects its power in the 1 Km dispersion compensating fibre (DCF) through a bidirectional WDM. At the end of the fibre coil, another WDM is connected in order to extract the residual pump power. The intensity sensing head (taper) is connected to one end of the WDM and to complete the ring cavity an 80:20 coupler is attached. This coupler allows 80% of the light to remain in the cavity and extracts the other 20% to monitor the output by an optical spectrum analyser (OSA).

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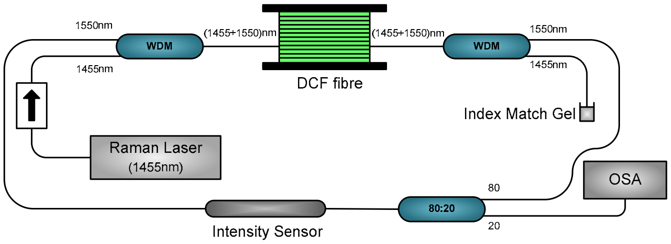

Figure 1 Schematic diagram of the propose intensity sensor

The produced Rayleigh scattering depends on the pump power injected in the optical fibre. The amount of P_p needed to generate the effect is small due to the high gain provided by the DCF fibre [8]. With a low P_p the obtained amplified spontaneous emission (ASE) is shown on figure 2 (dash line). When the P_p is increased a virtual distributed mirror is created [7]. The distributed mirror is mostly generated in the opposite direction of the Raman laser propagation due to de RS. In the other direction a distributed mirror is also produced but it does not have the same intensity (reflectivity) since it is due to the DRS of the initial RS.

The mirror created within the ring cavity allows that the reflections accumulated in some wavelengths, which in general correspond to the wavelengths with the greatest Raman gain. The proposed configuration has the advantage of tuning the generated peak wavelengths by selecting the appropriate Raman laser wavelength. In the implemented configuration, two peaks were generated inside the loop, specifically at 1556 nm and at 1565 nm, respectively (see figure 2 – solid line). The first peak is centred at 1556 nm (P_1), since is the wavelength that has the higher Raman gain. As the P_p is increased the peak power of P_1 starts to saturate and the peak at 1565 nm (P_2) begins to appear. For a P_p of 0.6W, it is possible to obtain peak powers of -10 dBm and -15 dBm, for the peaks centred in 1556 nm and 1565 nm, respectively. When the P_p is constant and attenuation is inserted in the ring the peak power of P_2 decreases. Therefore, to analyze the effect of stimulated losses, a taper (our intensity sensor) was added into the configuration.

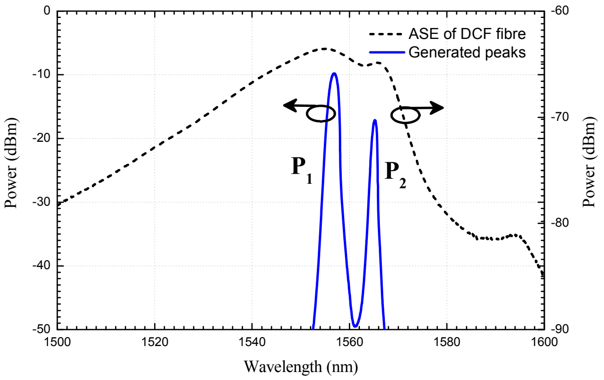

Figure 2 Output spectrum of the ASE of the DCF fibre and the generated spectrum inside of the ring cavity.

The fibre taper is a simple all-fibre device that allows the introduction of losses in the setup. In order to induce the attenuation, the taper was placed between two fibre holders and one of the holders has a translation stage in the longitudinal direction. The characterization of the taper was performed with a broadband source for twenty displacement positions. For each, the optical power spectrum was taken and the power loss was calculated (figure 3).

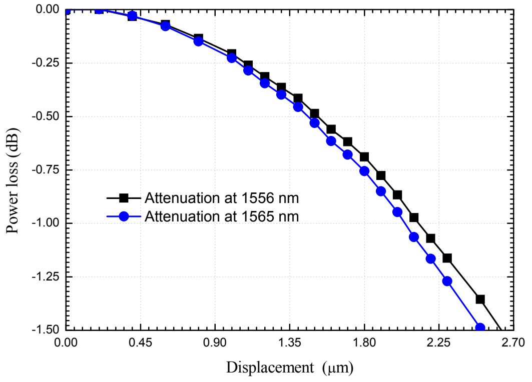

Figure 3 Characterization of the taper power loss

After inserting the fibre taper in the configuration of figure 1, the output spectrum was taken for each of the twenty displacements. With the bended taper, it is possible to induce losses of in the range of 0.0 to 1.5 dB. Some of the acquire spectra are shown in figure 4.

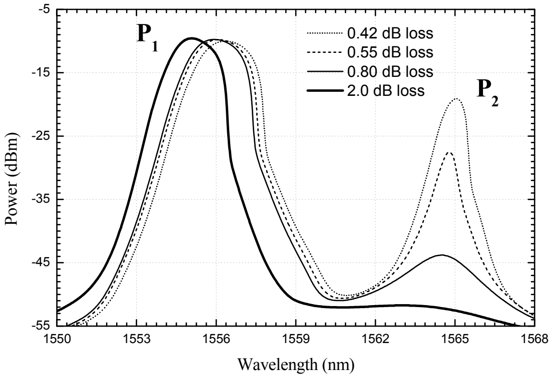

Figure 4 System response to power atenuation

In the above graph it is observed that with the increase of loss, P_1 presents a wavelength shift without any significant power fluctuations. On the other hand, it its noted that the greater the attenuation introduced by the taper, the lower is the amplitude recorded by the second peak (P_2). There is a correlation between the induced losses and the amount of power available in P_2 thus the system behaves as an intensity displacement sensor. The relation between the amount of loss induced by the taper and the peak power of P_2 is presented in figure 5.

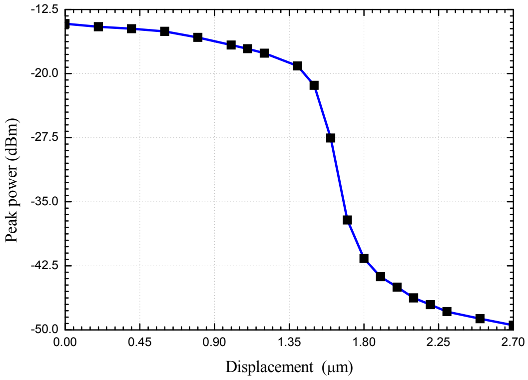

Figure 5 Variation of peak power of P_2 in relation to the displacement induced in the taper.

The system presents a suitable response, the power of P_2 decreases from the initial -15 dBm up to -48 dBm as displacement increase leading to losses of 1.5dBs. Moreover, as the peak P_1 under the same conditions presents a power variation of less than 0.5dB. It is possible to use it for cross-reference for a more accurate result.

3. CONCLUSION

An intensity displacement sensor based on a Raman laser assisted by Rayleigh scattering is demonstrated. The usually non-desirable Rayleigh scattering creates a distributed mirror inside a laser ring cavity that is able to select two wavelengths. One is due to the saturated Raman laser at the gain peak, and almost insensitive to cavity losses. The other appears at a secondary gain peak and is very sensitive to the cavity losses. The different behaviour of the two obtained peaks allows the measurement of losses with improved stability up to 1.5 dB.

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