AUTOMATIC AND ACCURATE LOW COST HIGH FREQUENCY CHARACTERISATION TECHNIQUE OF CHIRPED FIBRE BRAGG GRATINGS

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Abstract: We demonstrate a high frequency low cost technique for characterising the reflectivity and time delay spectral response of chirped fibre Bragg gratings. Wavelength resolution of 0.06 nm, time delay accuracy below 1ps, automatic and non-interferometric measurement are their main advantages.

Introduction

The use of fibre Bragg gratings (FBG´s) in telecommunications and sensing has been increased significantly during the last five years /1/. Recent improvements in the fabrication of fibre Bragg gratings lead to the production of long gratings with complex refraction index profiles /2/. Chirped fibre Bragg gratings have found important applications in optical transmission technology as dispersion compensators /3/, and as distributed sensors for strain measurements in the field of sensing /4/. To characterise such gratings, the time delay and reflectivity for each wavelength within their bandpass must be accurately measured. Several techniques have been developed so far, such as those using an RF modulated Michelson interferometer /5/ and those employing low coherence interferometry (LCR). Previous experimental results by using LCR techniques are very good /6/, i.e. time delay accuracy (1.7 ps) and wavelength resolution (0.18 nm) but both techniques rely on the use of optical interferometers and require signal path control and stabilization loops against environmental variations. Hence, we previously demostrated a robust technique based on measurements performed by a lightwave components analyzer (LCA) and an externally RF modulated tunable laser source, which overcomes interferometric limitations, adequated for a production line /7/. However, LCR technique has an important advantage related to low cost effective all-fibre system, eliminating expensive tunable laser equipment.

In this paper we demonstrate a new fibre low-cost technique for characterising the spectral response of chirped fibre Bragg gratings by using a white light source and a uniform Bragg grating. Experimental results have been compared to theoretical predictions in order to understand the effect of using a white source and a uniform Bragg grating to interrogate the chirped fibre Bragg grating at different RF modulation frequencies. High frequencies (~1GHz) are found to give best time delay accuracies (<1ps), while wavelength resolution is demonstrated as good as 0.06nm.

Description of the characterisation system

The basic configuration of the characterisation system is shown in figure 1. Output light from an electroluminiscent laser diode (SLED, inset) is filtered by using a 5 cm-long uniform FBG with 84% reflectivity and 3 dB-bandwidth, BW_u, of 0.06 nm (see figure 2, where resolution bandwidth, RBW, is 2 pm). The grating is mounted on a straining base to tune the bandpass grating (Äë$_B$~0.013nm/µm).

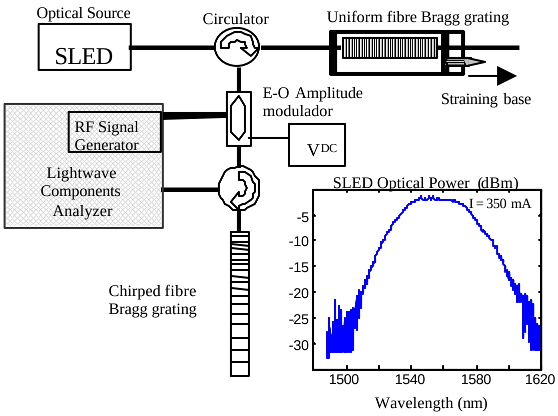

Figure 1: Schematic diagram of new chirped fibre Bragg grating characterisation system.

The optical signal is RF amplitude modulated by using an electro-optic modulator and an optical components analyzer (LCA) generates the RF signal. The modulated optical signal is reflected by the chirped grating under test, which was a 40 cm-long grating with a 3 dB-bandwidth, BW_c, of 4.1 nm (figure 2.a, RBW ~20pm) and dispersion slope of 880ps/nm (figure 2.b). Measurements are done in the LCA, which compares its output electrical current with the Ù component of its input photocurrent. The comparison of these currents yields the chirped grating modulus and group delay characterisation at the optical wavelength selected by the uniform grating provided Ù<<ù$_o$ /7/. Continuous stretching of the grating provides the spectral characterisation over the required wavelength range.

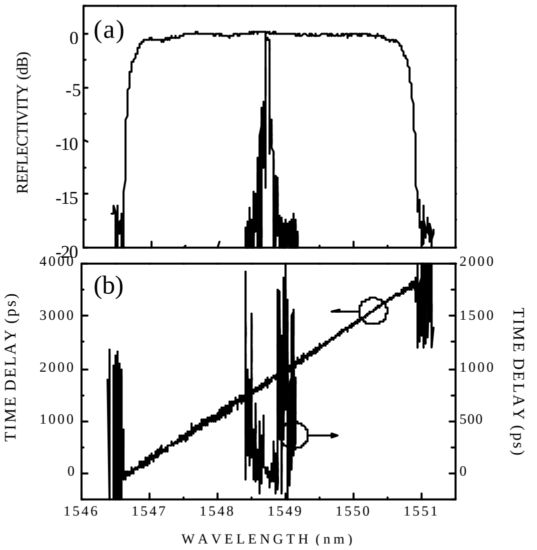

Figure 2: Characterisation of the gratings spectral response using an externally modulated tunable laser source: (2.a) Reflectivity, (2.b) Time delay.

Experimental results

Figure 3 shows the time delay measurements when using different modulation frequencies [0.315, 1, 2] GHz. The results are shifted in the vertical axis to show the linear behaviour and fits very well to the time delay characterisation shown in figure 2.b). Accuracy of the new system measurements are below 1ps, and the resolution bandwidth is given by the narrow bandwidth of the uniform grating (~0.06 nm).

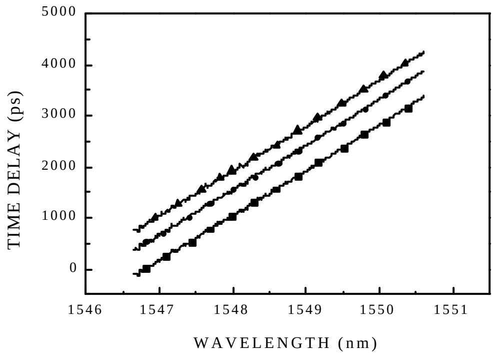

Figure 3: Time delay response of the chirped fibre grating, measured at different frequencies (■ 315 MHz, ● 1 GHz, ▲ 2 GHz).

The operation of the system at different RF frequencies has been explored by fixing the optical wavelength and scanning the modulation frequency from 300 MHz to 1 GHz. Averaging the obtained results over 5 optical wavelengths located at the bandpass of the grating, the time delay slope is plotted in figure 4 vs. modulation frequency. Dashed line shows the theoretical prediction in accord to the experimental results. Theoretical analysis will be shown in a later publication explaining that $BW_u << BW_c$ must be satisfied in order to guarantee the correct performance. The inset shows the calculated cuadratic slope errors, which are lower (below 1 ps/nm) at higher frequencies (1 GHz), as expected.

Figure 5 shows the electric transfer funcion in the [0.130-20 GHz] range when the optical wavelength is fixed at 1550 nm. The well known effect of the grating dispersion characteristic on the analog signal, called carrier supression, is similar to the measurements obtained when a tunable laser source is used. The main effect is a slight decrease of the electric power, also predicted by theoretical simulations (see figure 5).

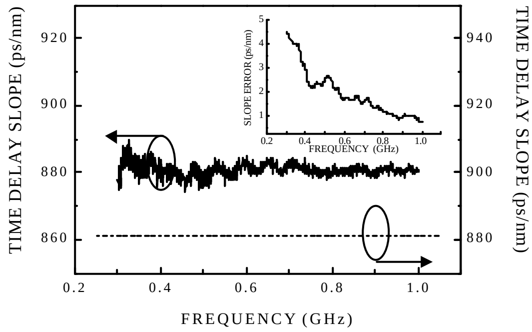

Figure 4: Time delay slope vs RF modulation frequency. Experimental (———). Theoretical predictions (- - - -). Inset: Time delay slope error vs. modulation frequency.

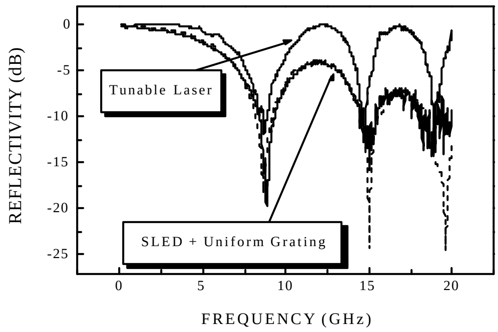

Figure 5: Dispersion effect on the analog RF signal. Experimental (———). Theoretical predictions (- - - -).

Conclusion

We have demonstrated a new technique for the characterization of the reflectivity and time delay response of chirped fibre Bragg gratings based on the external modulation of a white light source when it is reflected by a uniform grating. Wavelength resolution is 0.06 nm and accuracy has been demonstrated below 1 ps. Continuous spectral characterisation can be done by stretching the fibre. Measurements have been demonstrated at different frequencies in the [0.3 – 2 GHz] with increasing accuracy at higher frequencies. The technique does not need expensive tunable laser systems, is not based on optical interferometry and can be automatised in a production line.

Acknowledgements

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