IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

TEMPERATURE DETECTION FOR LPG-FBG USING MATCHED FILTER

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Abstract : In the current study, we suggest a configuration of a fibre bragg grating and a long period grating sensor utilised to concurrently measure ambient temperature. In order to determine changes in temperature and exterior refractive index, we describe the modeling of such a sensor and examine the reflected fiber bragg grating spectrum's amplitude and wavelength alterations. The findings demonstrate that the temperature affects the reflected wavelength shift and the reflected amplitude change of the fibre bragg grating is dependent on the fluctuation of the long period grating transmission spectrum.

***IndexTerms* - Long Period Grating, Matched Filtering, Fibre Bragg Grating.**

I.INTRODUCTION

In recent years long-period fibre gratings are finding increased applications in civil, industrial, and military fields, gain flattening of erbium-doped fibre amplifiers, band reject filters , refractive index sensors, bend sensors, temperature and strain sensors are quickly attenuated and this result in series of loss bands in the transmission spectra of the grating[1]. Fibre gratings can be divided into short period gratings and long period gratings depending on the grating period. While LPGs are characterised by mode coupling between the propagating core mode and co propagating cladding modes, which results in a number of attenuation bands in the transmission spectrum[2] centred at discrete wavelengths that confirm the matching condition of each coupled cladding mode, FBGs cause the coupling of the fundamental core propagating mode to its respective counter propagating mode.

In the final scenario, the external refractive index determines the resonance wavelengths of the LPG linked [3] cladding modes and any modification to the core and cladding guiding properties will alter the spectral response of the LPG. Many methods and setups have been thoroughly examined, tested, and suggested in the literature as a means of overcoming the strain-temperature cross sensitivity phenomenon and enabling multi parameter measurements.[4]These methods include set-ups based on dual-wavelength superimposed gratings titled FBG.FBGs inscribed on fibres of various diameters and hybrid LPG/FBG.

Numerous configurations have been suggested to independently measure the temperature and the refractive index of various aqueous solutions, such as the Mach-Zehnder interferometer constructed on tapered optical fibre[5], the hybrid cascaded LPG/FBG configuration integrated with a thermo stabilized flow cell, and the hybrid LPG/FBG structure UV-inscribed in a D-fibre.In this paper, Using an LPG and an FBG written in the same optical fibre section, we present and experimentally show a new optical fibre sensor that enables temperature . This is accomplished by measuring the wavelength shift and the amplitude modulation of the peak that only [6] corresponds to the FBG resonance. To our knowledge, this is the first time this strategy has been experimentally tested. This methodology has earlier been presented, but only a theoretical simulation is described.

II. PRINCIPLE OF ALGORITHM.

The foundation of fibre Bragg gratings [7] is counter-propagating mode coupling. The core propagating mode is reflected into an identical core mode that is propagating in the opposite direction in the case of a single-mode fibre. The refractive index and/or grating period alterations have an impact on the [8] FBG sensitivity. The fiber's refractive index is immediately impacted by strain and temperature, shifting the reflection peak and lengthening the resonance wavelength.

The co-propagating cladding modes and the core mode are encouraged to couple by the LPG. The period of the LPG [9], the sequence of the cladding mode to which coupling occurs, and the makeup of the optical fibre all have an impact on how sensitive LPGs are to environmental conditions. In this work, the temperature and the refractive index were measured simultaneously using a fairly straightforward hybrid [10] arrangement is proposed and demonstrated by simulation. The suggested setup should consist of an [11] Broadband source, a LPG, a FBG and the Storage Device. A fibre Bragg grating that is intended to be spectrally situated on one edge of the LPG should be put in place after it. The FBG needs to incorporate the LPG's transmission spectrum. At the OSA [12], the FBG's reflected spectrum may be measured. Although the LPG and FBG should not be positioned on the same section of the fibre, it is not an issue since they might be quite together.

Let's assume,
Adding of transmission and reflection coefficients of LPG-FBG,

$$YL=T+R \quad (1)$$

Where Reflection Coefficient is given as,

$$R = \frac{sinh^2\sqrt{(k^2-s^2)L}}{cosh^2\sqrt{(k^2-s^2)L-\frac{s^2}{k^2}}} \quad (2)$$

And Transmission Coefficient as,

$$T = \frac{k * sin^2\sqrt{(k^2+s^2)L}}{k^2+s^2} \quad (3)$$

Where,

$$k = \frac{\pi}{\lambda} v.dn$$

Now we need to find the temperature theoretically by using the below formuale,

$$\frac{\Delta\lambda}{\lambda_B} = E\,\Delta T \quad (4)$$

Each term can be defined as,
$\Delta\lambda$=Change in wavelength
ΔT=Change in the temperature
λ_B=Initial value
E =Transmission Coefficient of FBG.
Their values are,
$\Delta\lambda = 0.5\ nm$
$\lambda_B = 1546\ nm$
$E = 0.55 * 10^{-6}$

Equation (4) can be written as,

$$\frac{\Delta\lambda}{E\lambda_B} = \Delta T \quad (5)$$

Substitute the values of respective constants in equation (5)

$$\Delta T = \frac{0.5}{0.55*10^{-6}*1546}$$

$$\Delta T = 58.8℃$$

By substituting all the values in the formula theoretically, the change in temperature will be 58.8℃

III. RESULTS AND DISCUSSION

The wavelength shifts as a result of any perturbation, such as change in temperature. The wavelength shift is proportional to the applied measurement. A single LPG can therefore often be used to measure a single physical parameter. Matching filtering is the foundation of the suggested LPG peak detection method. This method involves matching the reflected LPG to a reference spectral signal (such as the Gaussian peak model).Since the Gaussian spectral signal resembles a reflected LPG signal, it was chosen. The narrow spectral band of the Mexican-Hat wavelet, which is nothing more than the derived version (2nd derivative) of a straightforward Gaussian function, is what led to its selection.

Additionally, we evaluated the corresponding sensitivity coefficients for temperature and measurements made with the same LPG-FBG in both transmission and reflection modes. Both in the LPG's reflection mode and transmission mode, we discovered comparable sensitivity coefficients. This is the first instance when the transmission and reflection modes of LPG are experimentally compared. We found the zero crossing point where the temperature wavelength differentiation is zero using LPG-FBG sensors. To support our previously published modeling work, we have experimentally demonstrated the temperature and wavelength spectrum of LPG -FBG.

Experimental verification is done for the suggested matched filtering technique for LPG-FBG peak detection**.**Fig1 displays the experimental data's normalized response**.** Applying the [13] suggested approach to the experimental spectral data, calculating the zero-crossing locations using Equation (5) and plotting its response in Fig 3.3.The LPG and FBG [14] resonance wavelengths shift as temperature rises, to shorter and longer wavelengths, respectively, changing the Bragg reflected spectrum in terms of reflected power modulation and resonance wavelength shift. The simulated transmission spectrum of LPG is plotted and the assumed reference signal as Gaussian is plotted in Fig 3.1

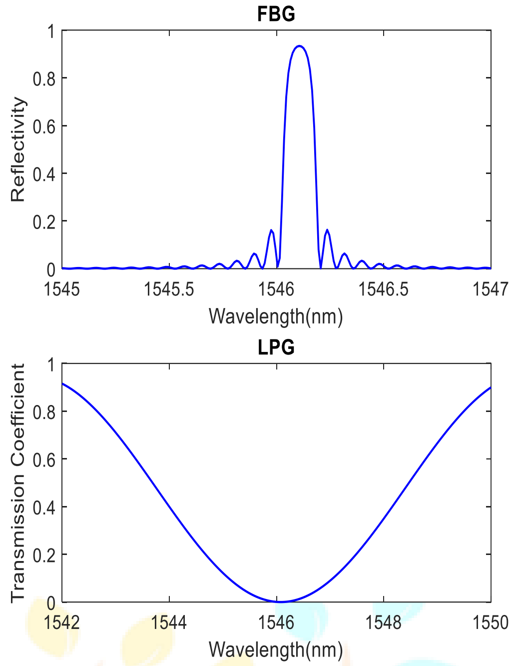

Fig 3.1: Gaussian Model Spectrum

The matched filtering techniques is applied to detect the temperature and the cross correlation and intensity response is determined which is plotted in below graphs.

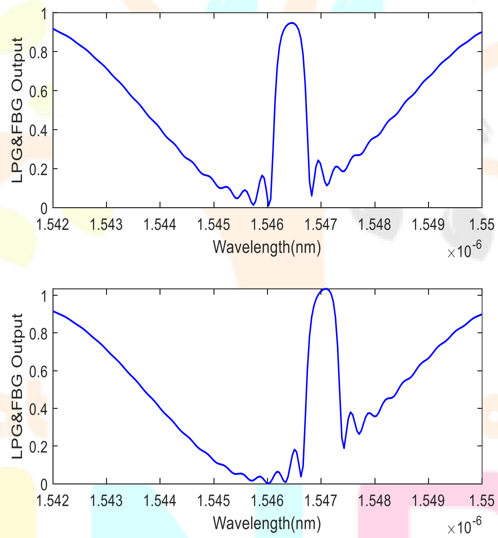

Fig 3.2: Cross Correlation of LPG&FBG

Experimentally, change in the peak at a point is determined using a method called Zero Crossing Point. The derivative is zero across that point. 1546nm is the zero crossing point, which means ΔT is 0.5nm and we have λ_B=1546nm. By applying **60**℃ temperature we found 0.5nm change in the peak of LPG-FBG.

Several LPG design adjustments that can switch the gearbox mode sensor to a reflective mode have recently been published in order to address these issues with gearbox mode LPG. The capacity of these sensors to detect a single measured when affected concurrently by axial and temperature was confirmed by experimental data. When building a long grating sensor, there is more freedom because the size of the fiber cladding can significantly affect the sensitivity. One LPG can sense several parameters since each connected mode's spectral dependence on the external parameters varies. Despite the fact that the LPG sensor's temperature sensitivity coefficient is one orders of magnitude larger than the FBG sensor's.

By applying different temperatures the peak will get change. We need to apply the temperature [15] which is above the room temperature then we observe the change in the peak. When we apply the temperature more than **50**℃ then we can observe the peak very clearly. We need to determine the change in the peak by applying different temperatures. To confirm the accuracy of the prediction of the zero-crossing points, the position of the zero-crossing point is measured at 1546.5 nm and the intensity is determined. The computed intensity response [16] is presented in Fig 3.2, and it can be seen that the highest intensity occurs at the same zero-crossing sites, which are 1546.5 nm. If the applying temperature changes the peak will also get change.

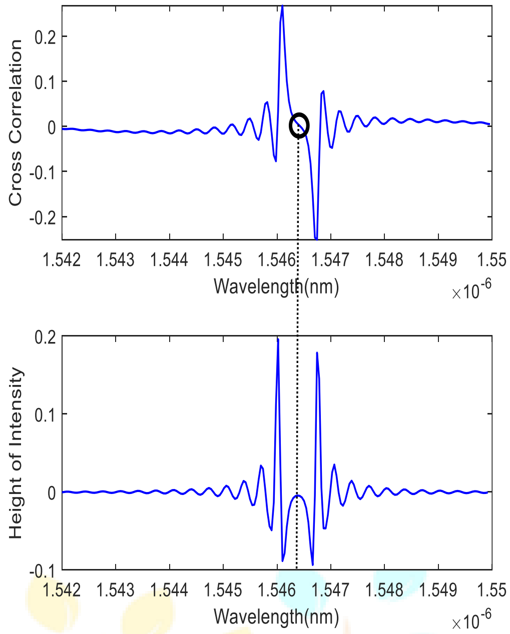

Fig 3.3: Zero Crossing Point

IV. CONCLUSION

An experimental demonstration and proposal of a hybrid grating-based sensor for temperature measurement are made. The LPG-FBG structure offers the ΔT measurement for wavelength values from 1542 nm to 1550 nm with a temperature adjustment between 30 °C and 80°C. LPG transmission spectra have an impact on FBG reflectance. The FBG and LPG structures combined in this sensor's special layout allow it to sense two parameters simultaneously.

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