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A COMPARATIVE STUDY OF FBG TYPES FOR PERFORMANCE OPTIMIZATION OF TEMPERATURE ARRAY SENSORS

By

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ABSTRACT

Although developed initially for the telecommunications industry in the late 1990's, Fiber Bragg Gratings (FBGs) are increasingly being used in sensing applications (mainly in temperature and strain sensing) and are enjoying widespread acceptance and use for proving to be one of the most efficient tools for their considerable advantages, over their electronic counterparts, such as, immunity to electromagnetic interference, potential to work in harsh environmental conditions, multiplexing capability, wavelength encoded (eliminating amplitude or intensity variation problems), their small size, light weight and high sensitivity.

Enhancing the FBG temperature sensor performance comes through precise control over its various characteristics; narrowing the Full Width at Half Maximum (FWHM), reducing the side lobes, raising the reflectivity to obtain high sensitivity besides steeping roll-off (side lobes suppression) for rejecting adjacent channels and assuring stable operation over increased temperature.

The main target of this thesis is to obtain an optimum performance for FBG-based temperature sensor which can be multiplexed with other FBG sensors to form an array. Accordingly, theoretical analysis and numerical comparisons are carried out to evaluate the performance of different FBG types including uniform, pi-phase shifted (πFBG) and various profiles of apodized FBGs (Gaussian, Hamming, Barthan, Nuttall, Tanh, Sinc, Raised Sine and Cos^8). This was done under a number of controlling parameters including grating length (L) and refractive index modulation amplitude (Δn_{ac}). Several techniques are used for judging the performance including peak reflectivity, number of observed side lobes, side lobes strength, side lobe suppression ratio (SLSR), FWHM, roll-off rate and ripple factor are also used.

Analysis and comparisons revealed that, the uniform FBG is not an optimum solution because of its broad FWHM and high level side lobes, although it has high reflectivity, acceptable roll-off rate and stable operation over increased temperature.

When compared (at constant L=10000 μm and $\Delta n_{ac}=4\times10^{-4}$) to uniform FBG, πFBG has achieved best results in terms of the introduced evaluation techniques with two peak reflectivities of amplitudes 99% and 98.53% and high ripple factor of 0.999, but unfortunately showed a remarkable failure when talking about the side lobes analysis and

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FWHM. Meanwhile, the Nuttall and Cos^8 apodized FBGs solved this problem with the lowest side lobes strength of -95.9783 dB and -58.107 dB, respectively, narrowest FWHM of 0.848 nm and 0.966 nm, respectively, highest SLSR of 100% and 92.62%, respectively, less number of side lobes (2 and 8 respectively) but at the expense of reducing reflectivity, ripple factor and roll-off rate. So, it is proposed in this thesis to integrate the Nuttall, Cos^8 apodization and pi-phase shift techniques to get the targeted optimum performance.

A modified hybrid FBG temperature sensor is proposed based on the integration of one Nuttall and one Cos^8 apodized FBGs separated by pi-phase shift. The analytical results of the reflection spectrum showed low side lobes of amplitude - 60.93 dB and few number of side lobes (2 only), narrow FWHM of 1.046 nm, high and steep roll-off of 95.22%, high reflectivity of 77.63% and availability of six peaks to increase the area and chance of detection in the field of temperature sensors array; besides the stability over increased temperature. Accordingly, these results have proved an optimum performance for the suggested FBG temperature sensor.

A further analytical study was conducted for the effects of increasing L and Δn_{ac} on the performance of the different types of FBGs. The obtained results showed that, advantages of increasing the grating length L include higher peak reflectivity, higher roll-off rate and narrower bandwidth, at the expense of increasing the side lobes and decreasing SLSR. While the advantages of strengthening the gratings (increasing Δn_{ac}) include higher peak reflectivity and keeping the number of side lobes constant, the expense is decreasing the roll-off rate, SLSR and increasing strength of side lobes and bandwidth.

A simple simulation setup design of temperature sensor is also introduced. This can be applied in real life applications where a large number of sensors are required such as industrial process control, fire detection systems and temperature profiling in electrical power transforms.

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