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Performance Evaluation of Fiber Bragg Grating Strain Sensor Integrating in WDM Communication System

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Abstract*—In this paper, a fiber Bragg grating (FBG) strain sensor is simulated utilizing OptiGrating software. Then the proposed sensor is integrated into the wavelength division multiplexing (WDM) communication system via OptiSystem software in order to evaluate its performance as a strain sensor. The proposed WDM system has 4–channels with NRZ modulation format and 100 GHz frequency spacing. According to the results, the degradation in the receiving signal reaching the limitation value (6 for Q–factor and 10E–9 for BER) at applied strain ranging from 170 $\mu\varepsilon$ –to– 180 $\mu\varepsilon$.*

Index Terms*—BER, Fiber Bragg strain sensor, Q-Factor, WDM communication system.*

I. INTRODUCTION

WDM is one of the most popular techniques used to increase the number of channels in fiber optic communication. WDM uses multiple channels that have different wavelengths that can be transmitted through the same fiber [1]. On the other hand, the FBGs are used in a wide range of sensing applications such as thermal, pressure and strain sensor [2], as well as in fiber optic communication systems as dispersion compensator [3], optical filter [4] and add/drop frequency in a WDM system [1]. Thus, its invention considered a milestone in the optoelectronics field. In addition, Yi-Lin Yu et. al, incorporated an FBG into the WDM system as a strain sensor to monitor unusual behaviors on that system, and give an indication to an optical switch to switched from fiber-optic to free-space optical system [5]. Furthermore, the simulation programs offer low cost and high design tolerances in practical, as well as decrease the computational time required to solve the theoretical complex equations. In this context, the abilities of both OptiSystem and OptiGrating simulation programs in the optoelectronics field have been demonstrated for decades and up to presents [6]–[8]. In addition, the combination between these two programs produces a perfect optical architecture as well as more reliability assembly. This incorporation was proposed in several published works such as design FBG dispersion compensator, strain/temperature sensor, and tunable filter via OptiGarting and integrating these architectures in OptiSystem software [9]–[13]

To the best of our knowledge, there is no published work incorporating the FBG strain sensor in the WDM communication system as an integrated assembly simulated between OptiGrating and OptiSystem software. In this work, this assembly is demonstrated and investigated under different strain conditions.

II. EXPERIMENT SETUP

This section includes three parts, namely, FBG strain sensor design, WDM communication system design and incorporating the FBG sensor into the WDM system.

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A. FBGs Strain Sensors Design

In this subsection, the OptiGrating software is used to design four FBGs strain sensors at center frequencies, namely, 1553.329 nm, 1552.524 nm, 1551.720 nm and 1550.918 nm in order to monitor the effect of the applied strain on the WDM system, the characteristics of the simulated FBGs sensors are depicted in Table-1.

TABLE-1: THE CHARACTERISTICS OF THE PROPOSED FBGS

Bragg wavelength, λ_B nm	1553.329, 1552.524, 1551.720 and 1550.918
Grating length, L	7 mm
Index modulation	0.0005
Grating period, Λ	0.534 μm

B. WDM Communication System Design

In this work, a 4-channels WDM system is simulated via OptiSystem software. The input signal is achieved from array laser diodes with wavelength ranging from 1553.329 nm to 1550.918 nm with a step of 0.8 nm, frequency linewidth of 10 MHz and output power of 10 dBm. Two erbium-doped fiber amplifiers are used in order to compensate the transmission losses with gain level and noise figure of 20 dB and 6 dB, respectively. The chromatic dispersion is compensated via 10 km of dispersion compensating fiber (DCF), with negative dispersion of -85 ps/nm/km.

C. Incorporating the FBG sensor into the WDM system

In this section, the proposed FBG strain sensor is incorporated within the designed 4 channels WDM system as illustrated in Figure 1.

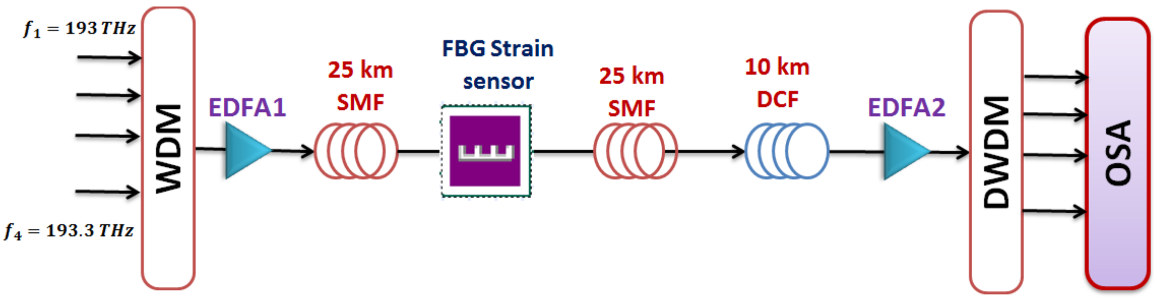

FIGURE 1: STRAIN SENSOR BASED ON FBG INCORPORATING WITH 4 CHANNELS 100 GHZ WDM COMMUNICATION SYSTEM.

III. RESULTS AND DISCUSSION

A. Characteristics of the FBG Strain Sensor

The performance of the proposed 4-FBGs strain sensors is investigated and evaluated under different strain conditions. The transmissivity and reflectivity at 0 microstrain are illustrated in Figure 2 (a, b, c, and d). Based on the design parameters adopted in OptiGrating software, the peaks reflected power was at 1553.329 nm, 1552.524 nm, 1551.720 nm, and 1550.918 nm.

Furthermore, the reflectivity of the FBG sensors at several micro strains ranging from 0 –to– 300 is investigated as depicted in Figure 3. According to the results, the center reflected wavelength for whole sensors is shifted about 0.37 nm as the strain increased from 0 –to– 300 µstrain. This shifting is due to change in elasto-optic effect and elasticity of the fiber which is caused by changing ineffective refractive index (neff) and the grating period

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(Λ) which is affected on Bragg wavelength (λB) [4, 13]. The analyzed data from Figure 3 is investigated in order to illustrate the shifting in center wavelength as depicted in Figure 4.

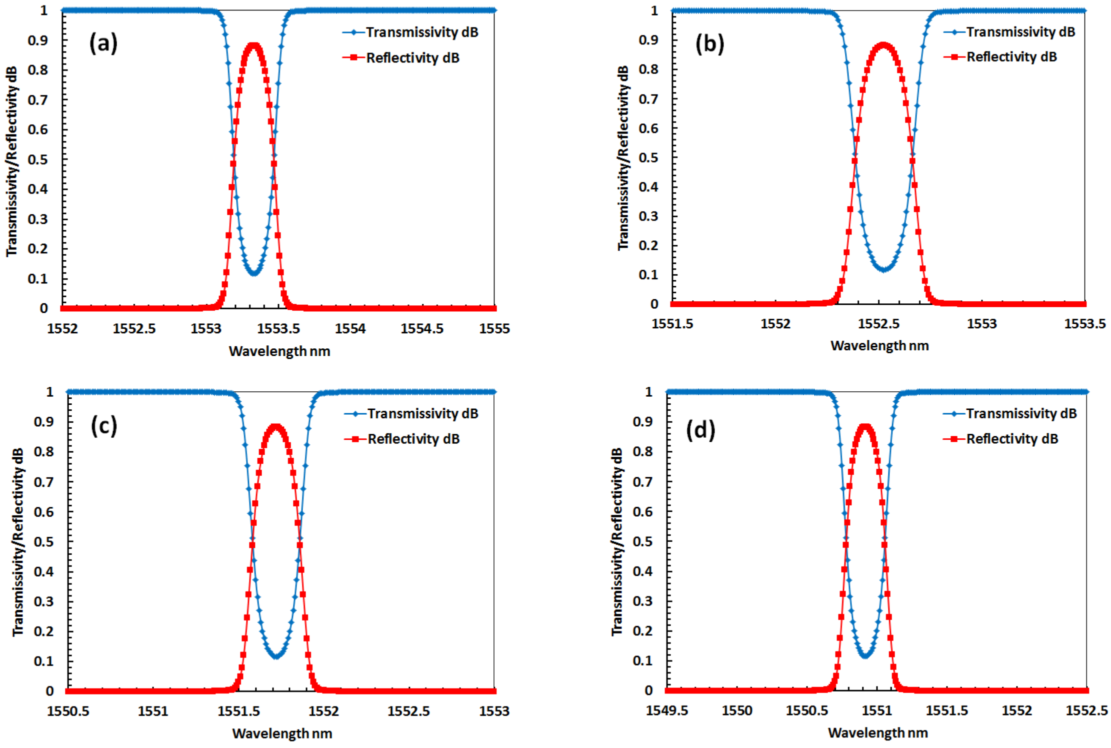

FIGURE 2: TRANSMITTIVITY AND REFLECTIVITY OF THE PROPOSED FBGS STRAIN SENSORS AT 0 STRAIN: (A) λB = 1553.329 NM, (B) λB = 1552.524 NM, (C) λB = 1551.720 NM AND (D) λB = 1550.918 NM.

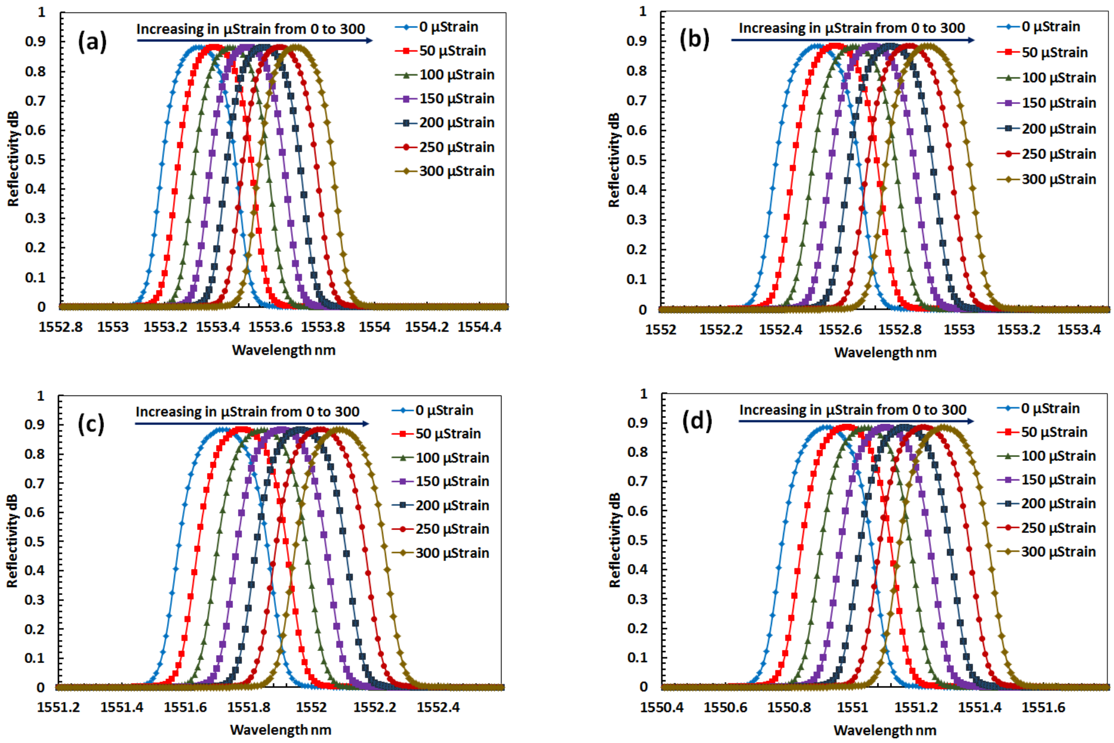

FIGURE 3: THE REFLECTIVITY OF THE PROPOSED FBG SENSOR UNDER DIFFERENT STRAIN VALUES FROM 0 –TO– 300 µSTRAIN: (A) λB = 1553.329 NM, (B) λB = 1552.524 NM, (C) λB = 1551.720 NM AND (D) λB = 1550.918 NM.

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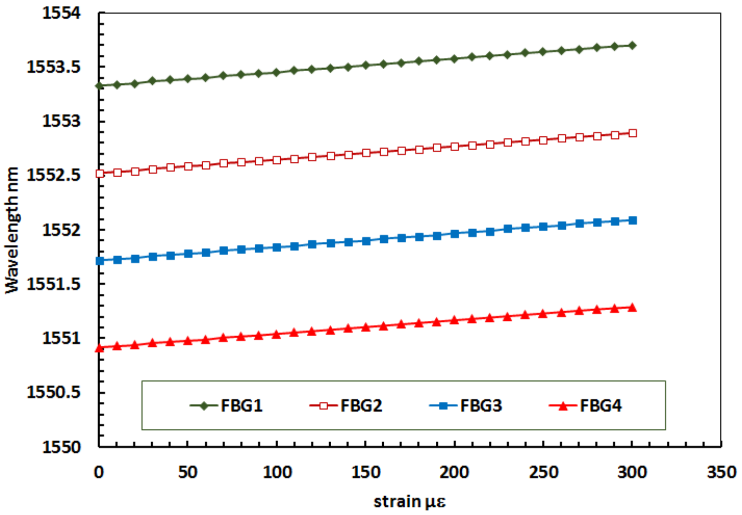

FIGURE 4: THE ANALYZED DATA FROM FIGURE 3 SHOWING THE APPLIED STRAIN EFFECT ON SHIFTING IN FIBER BRAGG GRATING WAVELENGTH.

B. Characteristics of WDM communication system

In this subsection, the performance of the proposed WDM system is investigated and evaluated under different strain conditions. Both of the BER and Q-Factor is adopted in this evaluation as depicted in Figure 5. The measured strain values were limited within approximately 6 and 10–9 for Q–factor and BER, respectively [14]. According to the results, as the applied strain increased the Q–factor reduced and the BER increased.

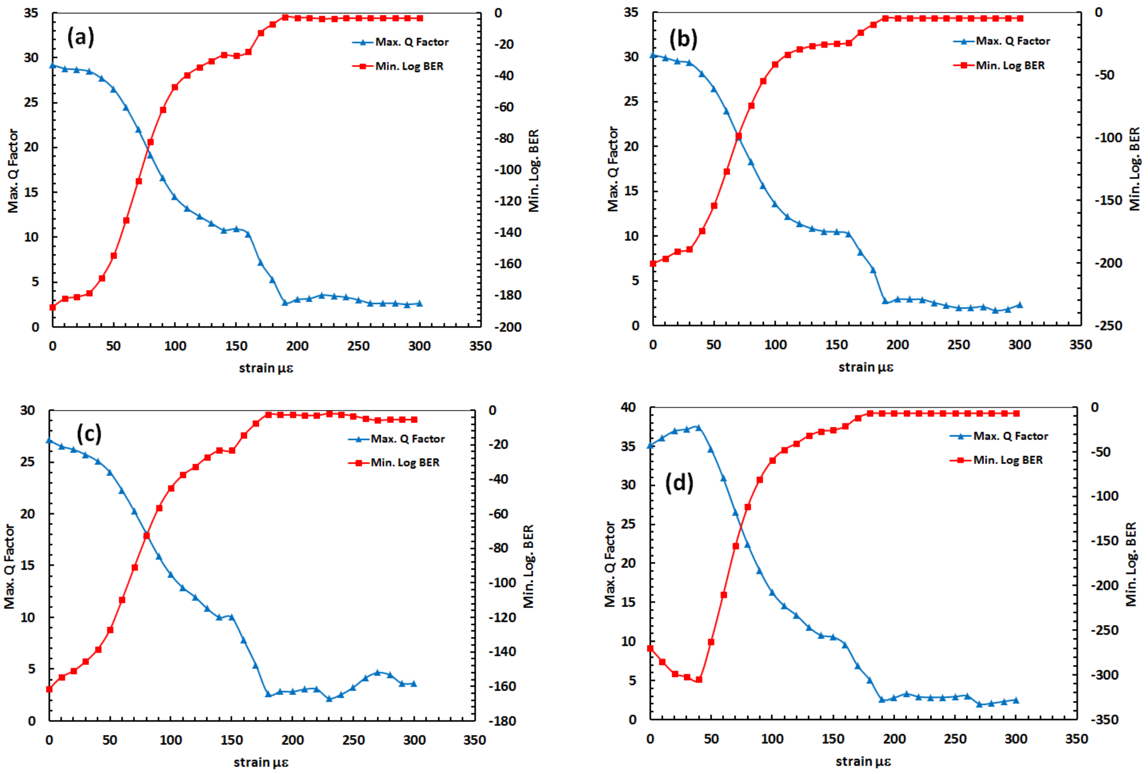

FIGURE 5: EFFECT OF APPLIED STRAIN ON BOTH OF THE Q–FACTOR and BER FOR: (a) λ_B = 1553.329 nm, (b) λ_B = 1552.524 nm, (c) λ_B = 1551.720 nm and (d) λ_B = 1550.918 nm.

This behavior indicates that the applied strain caused a redshift in the input signal wavelength as a result distorted the information in the receiving terminal of the WDM

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system. Moreover, for whole strain sensors the degradation in the receiving signal reaching the limitation value (6 for Q–factor and 10E–9 for BER) at applied strain ranging from 170 με –to– 180 με.

IV. CONCLUSION

The combination between OptiSystem and OptiGrating software was simulated and designed an integrated assembly includes 100 GHz WDM systems and FBG strain sensor. This work can be recommended as a communication system using the infrastructure of cities, especially via bridges, as it consists of a strain sensor. In addition, in the next step, we will combine a free-space optical (FSO) system to work as an emergency communication system for the fiber optic link. According to the results, the degradation in the receiving signal reaching the limitation value (6 for Q–factor and 10–9 for BER) at applied strain ranging from 170 με –to– 180 με.

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