Analysis of Fiber Bragg Grating for Indoor Applications

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***Abstract*— Fiber Bragg Grating (FBG) is the temperature measurement technology. FBG is the mainstream of optical communication and sensing. In this paper, an optigrating software is used to measure the temperature, stress and strain of FBG at room temperature. The temperature is measured in linear form 24º to 42º Celsius at the grating length 5000 µm. The comparison is also made with the phase shift of grating at same length with the Gaussian apodization. The result defines the dispersion and delay in wavelength. From the results of the simulation, it is determined that there is a linear connection between the temperature and the Bragg wavelength as well as in the strain change.**

***Keywords*— FBG sensor, Bragg wavelength, Grating Spectrum, FBG temperature sensing, Optical sensor.**

I. INTRODUCTION

In 1970, Corning Glassworks invented the optical Fiber sensor (OFS) which just appears after the practical optical fiber. Now, the Corning Inc. produced the first fiber with 20db/km below loss. In the decades, the optical devices like photo detector, optical fiber, and laser are very expensive which can afford only by telecom companies to avoid the old copper telephone network [3]. In 1980's, the huge dispersion of the optical fiber, the cost of optoelectronic devices became less [7].

Fiber Bragg Grating Sensor- Temperature Sensing

Fiber Bragg Grating (FBG) performance can also measure in the harsh environment during sunlight, rain, and the wind. FBG can use as an element transducing and convert the another sensor output, which can make changes in temperature and strain. It formed by the periodically changes in the core fiber refractive index in the propagation direction of optical radiation [1].

The key point of this paper is to evaluate the performance of FBG sensor at room temperature. Though simulate the error correction, it increases the performance of the FBG sensor system and measures the temperature on the short single mode fiber length.

FBG act as a spectral filter that reflects the certain light wavelength which is close to the resonance of Bragg wavelength $\Delta\lambda B$ and the remaining optical signal spectrum is released. For the temperature sensor system, the sensitivity of FBG has been developed and test the performance of the sensor system [2].

II. LITERATURE SURVEY

Dauda et al. in [1] have designed, developed and simulated fiber Bragg grating temperature sensor system. They evaluated the performance of FBG in severe environments exposed to direct sunlight, the wind, and rain. They have proposed a sensor system directly focused with convex and hand lens. They measured the temperature of FBG's sensor head. They launched broadband

laser source into the system using tunable laser source and both reflection and transmission spectra of FBG sensor were measured by optical spectrum analyzer (OSA). Their results of experiment represented that Bragg wavelength shift was directly proportional to temperature changes. [1]

Dauda et al. in [2] has designed and built a sensor system prototype of the outdoor temperature. Its performance is calculated at different times of the day. To decrease the optical losses of the Fiber Bragg Grating, the shortest optical fiber path used to connect the Fiber Bragg Grating system is 55.5m. It has a total connector loss 4.0dB and fiber loss of 0.3dB so giving an overall loss of the system as 4.3dB. [2]

Sharma et al. in [3] has shown the design & simulation of an OFBG sensor for stress and strain measurement. It also shows the methodology to arrive at the optimal grating pitch dimensions for a given interrogating wavelength. The wavelength chosen for interrogation of the FBG sensor is the 3rd window so as to reduce the attenuation of the light signal in the communication link from FBG sensor to the electronic instrumentation. From the graphical simulations, it can be recognized that rise in the grating pitch will modify the interrogating wavelength reflectivity. [3]

Mondal et al. in [4], a single sensor FBG with the two sections of different diameters is proposed and experimentally verified for discrimination and measurement of temperature and strain. A section of single FBG is fixed in HF solution to reduce the diameter of the fiber by a factor of <1/2 to increase its strain sensitivity. Different shifts of the λB of chemically etched and non-etched gratings caused by dissimilar strain sensitivities are used to differentiate and measure the strain and temperature. Maximum errors of ± 13με (micro-strain) and ± 10C are reported over 1700με and 60OC measurement ranges respectively. [4]

James and Birch in [5] have explained that fiber combined materials for use in structural applications are becoming more common. Though the sudden failures they are susceptible to creates a need for structural health monitoring to ensure safe use. Mechanical fiber composite structures such as airframes and wind turbine blades are desirable to have in operation as long as possible. So any structural health monitoring technology capable of operating when the structure is in service is advantageous. This technology is optical sensors, specifically FBG sensors, which can be entrenched in composite materials to measure the strain & temperature at a particular location. The data is viewed as the reflection spectrum which visually shows the trends and can be numerically analyzed. [5]

III. IMPLEMENTATION

Recently, the operator needs to measure and monitor some physical factor of OFS such as strain, temperature, stress, pressure, voltage, leakage current and much more. In the simulation of Fiber Bragg grating (FBG) sensor, the work is to be done on Optigrating 4.2. In this research, the quality of FBG sensor is to be measured at the temperature 24 to 42oC linearly at room temperature. The strength of FBG is user-defined and no chirping in the period to be followed. The grating length is all about 5000 μm to sensing the temperature of FBG at the Tunable laser filter. The temperature is calculated on linear because the demodulation of the Tunable optical filter become more consistent when the tuning wavelength is linear. The linear displacement of optical fiber sensor represents with a Single Mode Fiber (SMF). The changes can take place in the wavelength of FBG due to temperature and strain, it can represent as $\frac{\Delta\lambda}{\lambda_0} = (1-\rho_e) * \varepsilon + (a_\wedge + a_n) * \Delta T$, whereas $\Delta\lambda$ represents the Wavelength shift, λ_0 represents the initial wavelength, ρ_e defined the strain-optic coefficient, ε is the strain experienced via the grating, $a_\wedge$ is the thermal expansion coefficient and a_n defines the change in refractive index. Due to changes in temperature both expressions defines the grating expansion. The figure 1, show the working of FBG sensor, how the core and cladding transmit and reflect the Bragg wavelength in the spectrum response.

The figure 1, shows the working principle of FBG sensor. Figure 1 depicts the temperature changes effect on the FBG core and Cladding, and the result is displayed in the transmission spectrum and reflection spectrum.

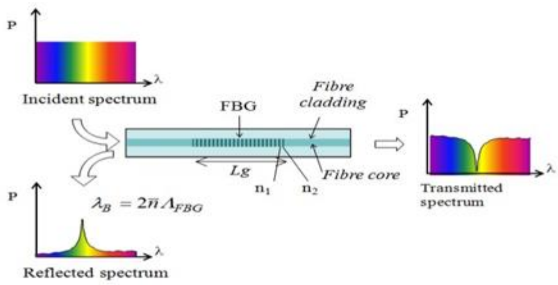

Figure 1: Working Principle of FBG Sensor

The comparison is also made to show the performance of FBG sensor on the same length and temperature with the drag of phase shift about length 5000 microns. The result is relatively different as we compare the result of FBG sensor at same room temperature with the Gaussian strength of 5.5 taper's parameters. The key point of this paper is to sense the temperature of FBG in a linear form about 24 to 42oC fix at a different wavelength to show and compare the dispersion and delay of transmission and reflection in refractive index. The parameters will be addressed like this at same temperature:

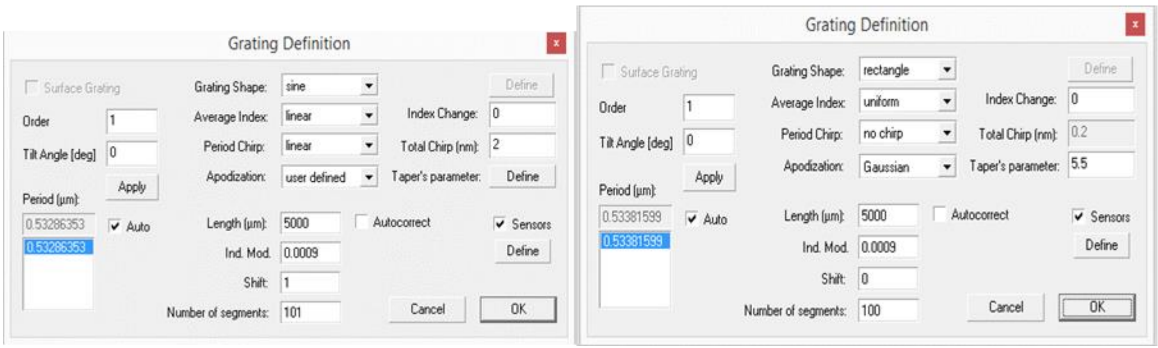

Figure 2: Parameters for FBG Sensor

IV. RESULT

As we implement the dispersion and delay performance of FBG sensor and compare in the phase shift grating, the pulse response of both the FBG has different, shown in figure 3 and 4. The figure 3 shows the simulation result in the phase shift form, the result of transmission dispersion became complex to determine and reflection effects on transmission of the refractive index.

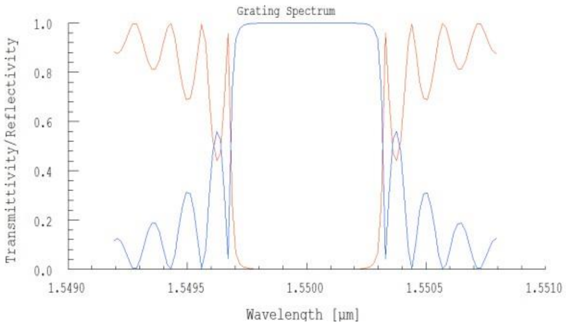

Figure 3: Pulse Grating Spectrum with phase shift

Figure 4 shows the simulation result without phase shift form. So, the result of both the transmission and reflection can measure easily and do not make an effect on each other during transmission and reflection.

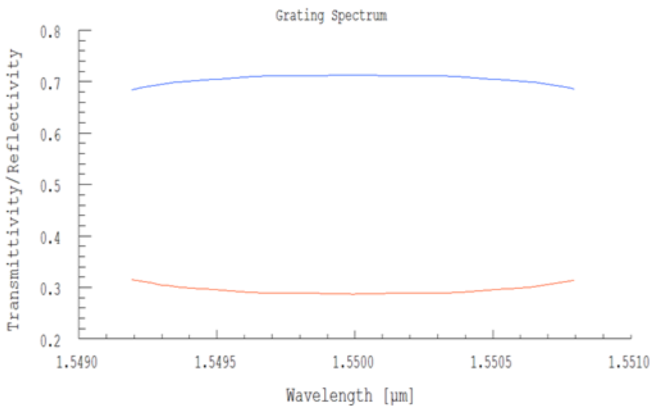

Figure 4: Pulse Grating Spectrum without phase shift

The result of the grating length is shown in figure 5 and 6 in the 3-D view.

In figure 5, the result of 3-D view depicts with phase shift grating which displayed the result on the length of grating 5000 µm and the length of phase shift 5000 microns with the Mesh (X and Y factor of transmission and reflection). The result in 3-D view of transmission and reflection show on the length about 10000.0 µm. In figure 5, the shift of phase in grating make more impact on the transmission rather than reflection. It depicts more dispersion (in figure3), in the transmission and reflection. Both the effects can see on each other.

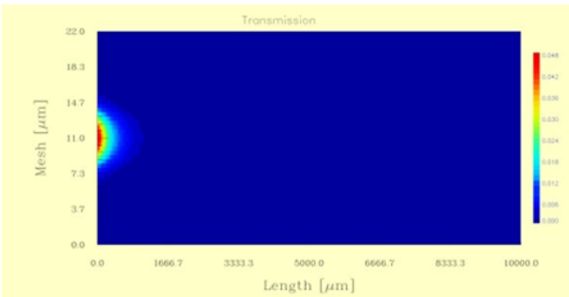

Figure 5: 3-D view of FBG sensor with Phase shift

In figure 6, the result of without phase shift grating displayed the result on the length of grating 5000 µm with the Mesh (X and Y factor of transmission and reflection). The result of both the transmission and reflection make no more impacts on each other rather. It makes transmission easily on Bragg wavelength and reflection. In figure 4, the length of transmission and reflection can measure easily, and the performance of FBG sensor make less dispersion during transmission and reflection.

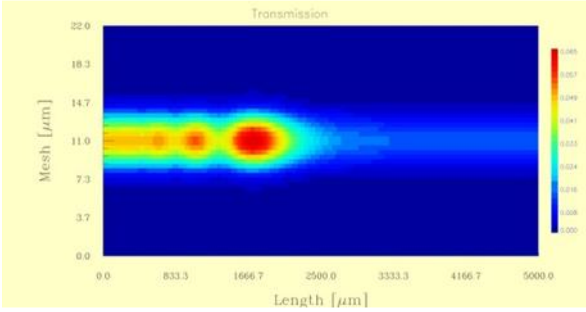

Figure 6: 3-D view of FBG sensor with Phase shift

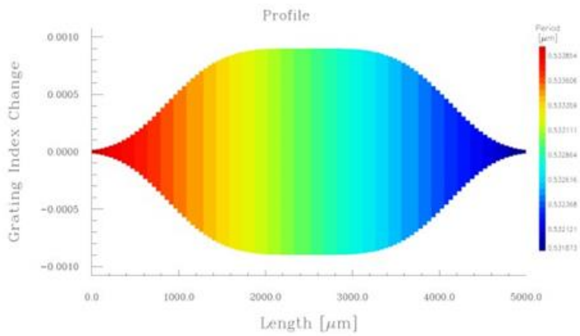

Figure 7: Complete result of FBG sensor on linear temperature

Comparison of Pulse Response and Spectrum

The result compares two parameters i.e. Pulse and spectrum response.

TABLE 1: Comparison result of Pulse and Spectrum grating temperature

PULSE		SPECTRUM	
Trans- mission	**Reflection**	**Trans- mission**	**Reflection**
Grating Spectrum 0.3	Grating Spectrum 0.69	Delay 20.5 (PS) (approx.)	Delay 60-0 (PS)
Input Pulse Intensity 1.549-1.555	-	Dispersion 0 (PS/nm)	Dispersion -0.1 to 400 (PS/nm)
Output pulse Intensity between -100 to 100 Time PS	Output Intensity Between –100 to 98 PS	Cumulative Phase 0 to – 200 rad	Cumulative Phase -0 to 190 rad

In table 1, the result of both pulse and spectrum show the input and output of dispersion and delay of both transmission and reflection on the simple sensing temperature of FBG.

Comparison Result of Previous and Current Research

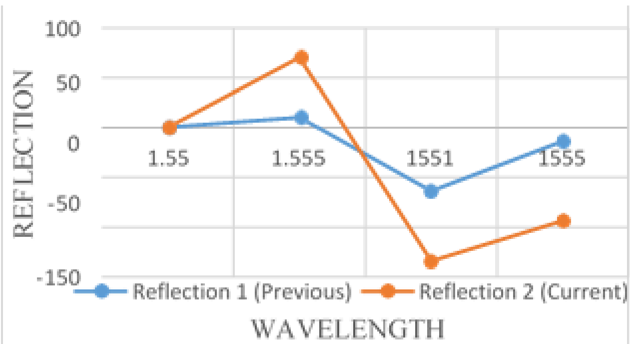

Figure 9: Comparison of reflection in spectrum

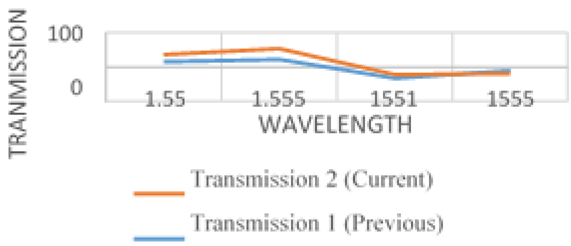

Figure 10: Comparison of transmission in spectrum

The figure 9 (Previous research) and 10 (Current research) shows the comparison result of Bragg wavelength with indoor temperature were observed for the reflection and transmission in the spectrum response. Due to thermal expansion, the temperature changes in the refractive index neff in the external environment.

In the previous Figure 9, the simulation of reflection and transmission has changed with the changes in temperature. The transmission has no stability in the linear temperature, but that was good experiment set up against outdoor temperature. While in figure 10 the transmission and reflection have on the same level with less dispersion value at the Bragg wavelength.

In figure 9, the value of transmission and reflection became low at the wavelength 1.5 to 15 µm i.e. on 1.5 lengths the value of reflection is 0.5 to 10.4 and the transmission is 15.6 to 22.4 whereas in the current research the value of transmission has little stable on the length 15 µm. i.e. The value of reflection is 0 to 60.2 at the 1.555 and at the 15µm reflectivity is -63.7 to -13.7 and the transmission value is 20 to 31.5 at 1.555 µm and at 15 µm wavelength the transmission became 10 to -8.6. Hence, in the current research the transmission has less dispersion than reflection in the fiber core on the grating length 5000 µm.

The entire value is taken randomly according to the length to compare the dispersion and delay of the FBG sensor on the both transmission and reflection. The result of both the research is measured at the temperature 24 to 42oC at room temperature.

V. CONCLUSION

In this paper, the performance of FBG sensor entirely depends on the strength and length of the grating to be transmitted and reflected. In this research, the comparison also shows the effects of dispersion during a shift in the phase of Bragg wavelength. The different environmental condition made an effect on the central wavelength of FBG sensor. In the result, the linear chirp FBG has shown the less dispersion. On the other hand, the Gaussian wavelength has shown the less dispersion on the non-chirping FBG. The simulation result of FBG sensor can measure their temperature, photoelasticity, and thermal- optic parameters by increasing the temperature of FBG in the Gaussian form in the same length of grating and phase shift with increasing the shift value of phase up to 5 dB. The result of FBG sensor calculate on outdoor and also.

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