Development of GUI Temperature Monitoring System based on Thin-Film Optical Filter

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الخلاصه

في السنوات الاخيره زاد الاقبال على المتحسسات الضوئيه بصوره هائله لما تحتويه هده المتحسسات من مزايا كثتره واهما حزمه التردد الكبيره، وعدم تأثرها بالموجات الكهرومغناطسيه، واقتصاديه الكلفه ، اضافه يمكن استخدامها تحت اي ظروف وفي درجات حراره عاليه. لهده الاسباب والمميزات تم انجاز متحسس حراري باستخدام مرشح يدعي (المرشح الضوئي الرقيق) الدي يتميزبدرجه تحسس عاليه ودقيقه بدلا عن المرشح الالياف الضوئيه.ولهذا – فيهذاالعمل – قدتم تصميم متحسس ذكي يبحث قيمةالعتبة بدون اي معلومات سابقة لتلك التوزيعات الاحصائية وذلك عن طريق تنفيذ خورازمية مبنيه على علاقه الحزمه الضوئيه الساقطه على المرشح الضوئي وعلاقتها بدرجه الحراره ، وتم تنفيد هدا النظام بثلاثه اجزاء وهي منظومه جمع البيانات وجزء متعلق بعرض المعلومات وربطها بجهاز كومبيوتر– تداخل المستخدم الخطي– والجزء الاخير الدي هو جهاز المتحسس الضوئي. لقد تم بنجاح فحص مصداقيه هدا الموديل الجديد المقترح لدرجات حراره عاليه تصل ال 30 الى 300 سليزي بتردد طوله الموجي 1552.93 الى 1557.25 نانو ميتر

الكلمات ألمفتاحيه: تداخل المستخدم الخطي، درجه الحراره ، المرشح الضوئي الاليا ف الضوئيه، المرشح الضوئي الرقيق

Abstract

Fiber optic sensors have progressed rapidly in recent year as because it has many advantages over other types of sensors in terms of freedom from electromagnetic radiation, wide bandwidth, economy, can withstand high temperature and under harsh environment. Due to those reason a thermo sensor based on fiber optic which utilizes a thin-film optical band-pass filter has been developed. However, the proposed system has advantages over the fiber Bragg grating sensor which can observe the temperature in small area and low transmission loss. The simulation software is used to design a Graphical User Interface (GUI). The GUI system allows the user to monitor the condition and the status of the current temperature. The monitoring system presented in this paper is divided into three basic sub-systems which are retrieve the real-time data system, displaying out the data system, and warning system. This GUI system used to collect the data and process the data for displaying the current data and further checking as a history data has been keep. The values obtained of thermo sensor are measured as 30°C till 330°C and the wavelength values are between 1552.93nm till 1557.25nm.

Keyword:-GUI; FBG; optical power; Temperature; Labview.

1. Introduction

A fiber optic sensor is a sensor that uses optical fiber either as the sensing element, or as a means of relaying signals from a remote sensor to the electronics that process the signals. Optical sensing techniques offer a high sensitivity to a wide range of measured (remote sensing) with a wide dynamic range those are measuring a physical parameter such as temperature, pressure, and strain. Moreover, previously proposed sensing techniques faced a real challenges if the environment is not suitable for traditional sensors such as electrical sensors (Giovanni,2000; Takahashi, 1995 ; Stanley,2006). For instance, in the presence of strong electromagnetic (EM) or microwave interferences for the electrical sensors, it could be a challenge to shield a thermocouple for accurate and reliable temperature measurement. Moreover, any time such interferences are present in a given application, the optical sensing technology is probably the best solution for such limitations (Yu and Yin , 2002) ; (Sathitanon and Pullteap,2007) and (Born and Wolf ,2002). Moreover, innovative or eveloped sensors based on optical fibers are considered the ideal solution device to overcome the limitations of other sensing techniques that capable of many applications advantages such in nuclear reactor which operates continuously up to 400ºC. However, in such application the features of the proposed sensor will be smaller size, light weight, faster response, less expensive, easy to use, and user friendly and more multi-functions.There are variety types of different fiber optical sensor available in the market those are distributed sensors, Michelson Interferometer, Fabry-Perot interferometer sensor, Fiber Bragg grating (FBG) optical sensor, and Thin-film optical filter (Beard and Mills,2006 ; Kersey *et.al.*,2007; Yang *et.al.*, 2010; James and Tatam, 2003).For the Basic fiber optical temperature sensor, its significant disadvantage is that the temperature sensing range is very limited. However, for the Michelson Interferometer a good-quality reflection mirror is required for the Michelson interferometer. In addition, part of the light is fed back into the optical source due to the complementary output. This can be extremely troublesome for semiconductor diode laser sources. An optical isolator is needed to minimize this adverse effect. For the Fabry-Perot interferometer sensor, Fabry-Perot interferometers do not require servo control of a fiber stretcher or management of a reference fiber, but it do not allow much more than a coherence length of sensor length. The major disadvantage of the Fabry-Perot interferometer is that at any one position multiple wavelengths will be passed by the filter. The spacing between these responses is called the free spectral range. Although, this problem can be solved by placing a monochromator in cascade with the Fabry-Perot interferometer to filter out all power outside the interferometer's free spectral range about the wavelength, but the value of the spectrum less accurate. Fiber Bragg Grating (FBG) sensor is considered the well know sensor but FBG suffer from various limitations. The important disadvantage that it’s can address only one grating at a time; other than that, FBG sensor unable to probe in small area. Moreover it is less sensitivity to vibration and heat comparing with the Thin-film optical filter sensor. Each of the above type of sensors has their own prone and cone due to the application and field. Based on the above mentioned limitations of the others fours type of sensor, optical thermo sensor based on thin-film is considered in this work.

1. System Design

Figure 1.1 shows the main blocks of the layout diagram of the optical circuit system adopted for simulation. The basic operation of the system is simulated when the light source passes through the fiber optic link, and then the different wavelength will be assigned for low pass n-Butterworth filter in 3rd order. For the system setup, the (Butterworth Optical Filter1) BOF_1 wavelength is 1552.36nm; the BOF_2 wavelength is 1552.25nm; the BOF_3 wavelength is 1552.93nm. The narrow spectrum that satisfies the thin film filter condition will be filters out and result gain from the optical power meter. As it appears from the diagram, the system consists of a transmission section, medium section and receives section. The transmission section comprises a pseudorandom bit sequence (PRBS) generator, where different wavelengths for simultaneous measurement of several thin film optical band-pass filter on an optical fiber end distributed along an optical fiber. In other word, the pseudorandom bit sequence generator sends the bit sequence to the NRZ pulse generator. The signal pulses modulate the LED optical source by Mach-Zehnder Modulator. After that, the signal is then travel thought the single mode fiber (SMF) which the SMF is category in the medium section. For the receive section, the signal is then separate in 13 sets of Butterworth filter that induce with different specific wavelength value by using de-multiplexer component. The Wavelength, λ value is calculated out base on the below formula : (Giovanni,2000; Takahashi, 1995 ; Stanley ,2006)

$$\lambda = (0.0144*T) + 1552.5 \qquad (1.1)$$

where, T = Temperature (°C), and the wavelength (λ)of 1552.5 is the center wavelength (nm)

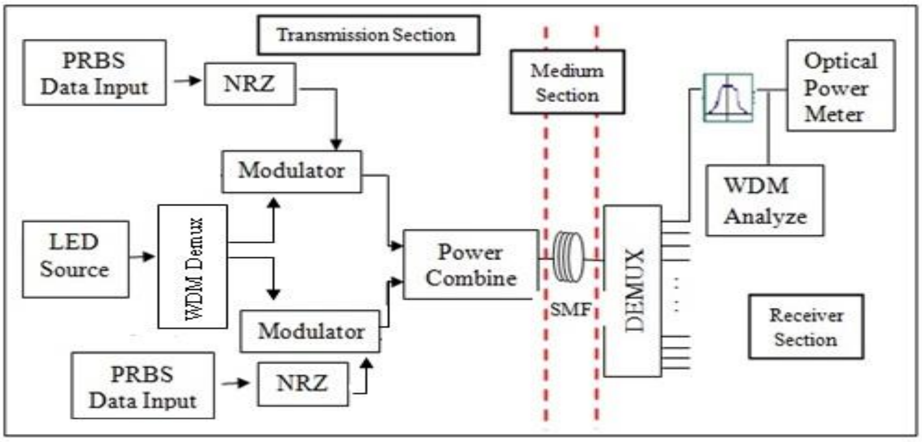

Figure 1.1 Proposed Simulation Block Diagram

The LED has been used as an optical source for this system as because it is inexpensive comparing with the LASER which makes the system more cost-effective. Other than that, LASER is not cost effective for use at low bit rates over short distance. As stated before that LED is inexpensive thus is a cost effective alternative choice. Besides that, LED no requirement for synchronization and simplicity of encode structure design. Standard Single Mode Fiber (SMF) was used for all the links considered. The single mode fiber has an attenuation of 0.2dB/km, a dispersion of 16ps/nm/km, a dispersion correlation length of 10km. The temperature has been calculated from the measurement of the wavelength shift of the interference. The thin film filters are known to have a Butterworth response and are commonly modeled as 3rd order of the Butterworth optical filter. Thin film filters have better filter amplitude response leading to lower bandwidth reduction. The proposed model is a pure optical system based on Butterworth optical filter designed to have as flat a frequency response as possible in the passband . The proposed model is illustrated in Fig. 1.2.

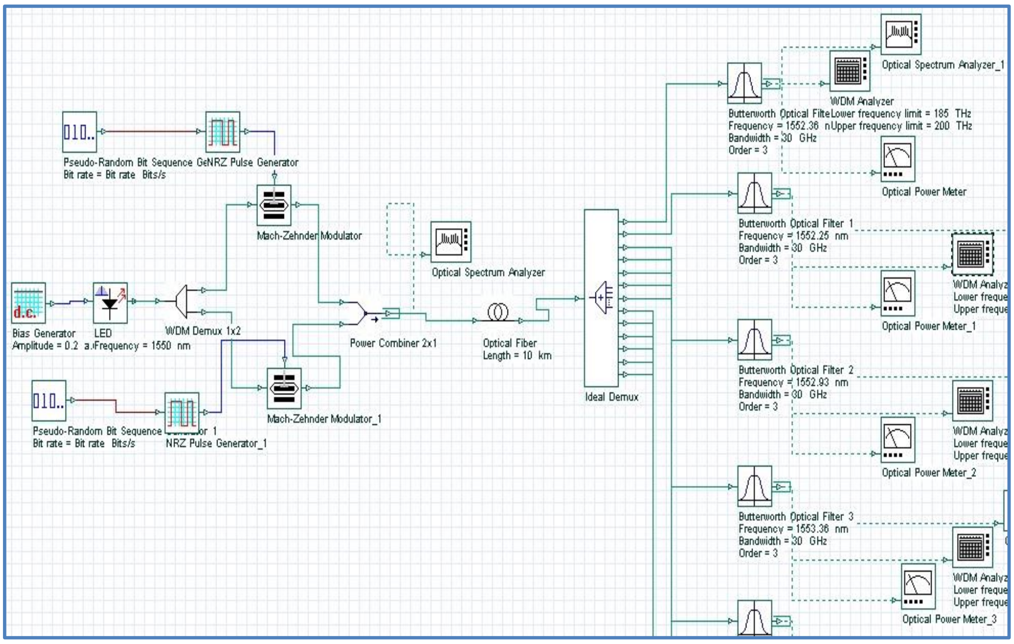

Figure 1.2 Simulation Model of Optical Thin-film Temperature Sensor System in OptiSystem

Moreover, in order to show the calculation of wavelength value with respect to a typical temperature grade. Let us consider calculating wavelength for temperature, T=30°C by utilizing Eq.(1.1)wavelength for a temperature of 30^{o}can be calculated as :

λ= (0.0144*300) + 1552.5

Therefore, wavelength, λ = 1552.93

The follower wavelength parameters are performing further in the Table 1.1.

Table 1.1 Temperature value as a function of Wavelength value

Temperature (°C)	Wavelength (nm)
-10	1552.36
0	1552.25
30	1552.93
60	1553.36
90	1553.79
120	1554.23
150	1554.66
180	1555.09
210	1555.52
240	1555.96
270	1556.39
300	1556.82
330	1557.25

2. Simulation Results

The simulation results depicted in this section are based on OptiSystem software by *Optiwave*^{TM}. Figure 1.3 illustrates the relationship between power and temperature, and it clearly shows the system operated at different power values is inversely proportional with the temperature changes. For a high temperature the power needed is low, the units measures for the power (y-axis) is dBm. Also, the Figure clearly shows that the outputpower decreases when the temperature increases. For the temperature at 90°C and 210°C the power systems are 86.309 µW and 84.480 µW respectively. The power is decreased exponential with the increased of the temperature value which is the main advantages of using Thin-flim Filter. Figure 1.4 shows the relationship of the wavelength as a function of Temperature.

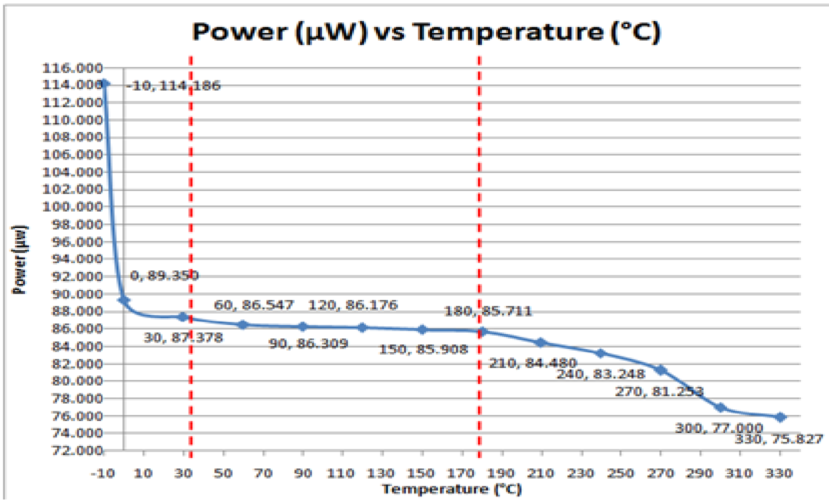

Fig.1.3 Output power versus Temperature for the proposed system

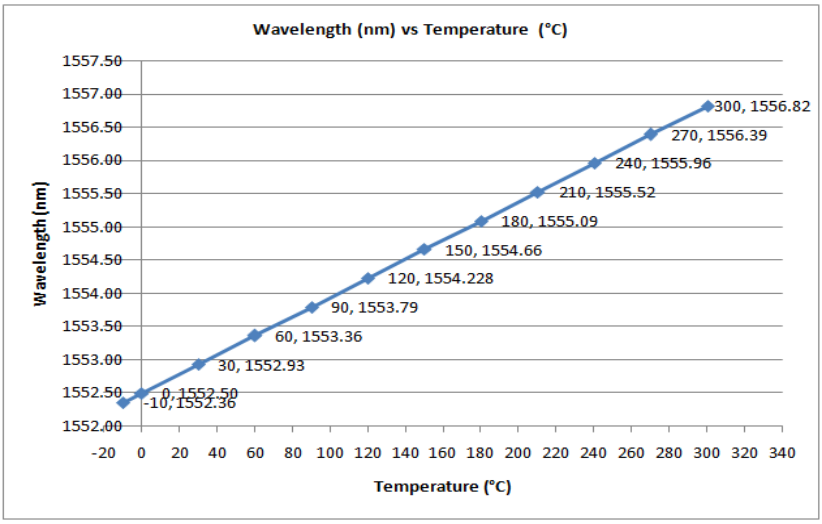

Fig.1.4 Wavelength as a function Temperature based Thin-Flim filter

Figure 1.5 presents the relationship between the wavelength and power. It shows that the power is decrease exponential with the increasing in wavelength. For example, when wavelength is 1555.09 nmfor fiber length 10 km the power is 85.711µW. Note that, the power gap between the 1552.50nm and 1552.36 nm is very big compare with the other gap of wavelength value. For the wavelength changing in the value has small significant changing in the wavelength. The minimum temperature is set to be -10°C and the maximum temperature is 330°C for the both wavelength value is 1552.93nm and 1557.25nm respectively. The wavelength difference for both wavelengths is 4.32nm which are changing range is very small. Also, the Figure depicts the relationship between wavelength and temperature, and it clearly shows that when the system operated at the different power, the effect of distance on the wavelength different too. In short distance of wavelength the power (dBm) that need to transmit is low compare to the long distance of wavelength that power (dBm) requires is high.

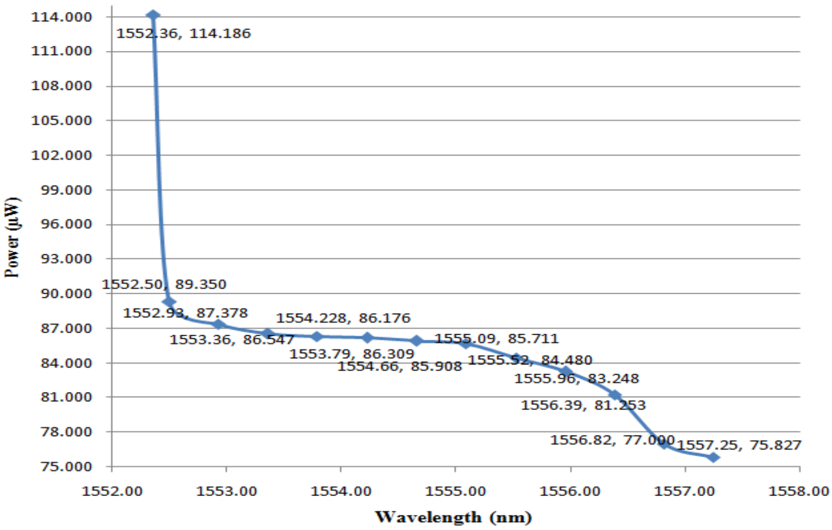

Fig 1.5 Power as a function of Temperate based Thin-Flim filter

Table 1.2 clearly shows that the power decrease the wavelength increase with the increasing distance. For example with the wavelength of 1552.5nm and

1556.39nm the power systems is 89.35µW and 81.253µW respectively. The power is decrease exponential with the increase in wavelength.

Table 1.2: Relationship between Power (µW) and Wavelength (nm)

Wavelength (nm)	Power (µW)
1557.25	75.827
1556.82	77.000
1556.39	81.253
1555.96	83.248
1555.52	84.480
1555.09	85.711
1554.66	85.908
1554.23	86.176
1553.79	86.309
1553.36	86.547
1552.93	87.378
1552.50	89.350
1552.36	114.186

The table presents the relationship between the wavelengths and power for different specific wavelength. It shows that the power is decrease exponential with the increasing in wavelength. For example, when wavelength is 1555.09nmfor fiber length 10 km the power is 85.711µW. Note that, the power gap between the 1552.50nm and 1552.36nm is very large compared with the other gap of wavelength value. Therefore, the wavelength changing has an insignificant changes effect. The minimum temperature is set to be -10°C and the maximum temperature is 330°C both of the wavelength value is 1552.93nm and 1557.25nm respectively. The wavelength interval of this both wavelengths is 4.32nm which are changing range is very small. Figure 1.6 illustrates the result of a GUI system in this project based on LabView software. There are two result waveform graphs displaying the signal frequency and the relationship between the wavelength and temperature graph plot.

Besides that, this GUI monitoring system has a table that displaying the current temperature value , status of the system and current temperature on time/date. Other than that, all the data can be saved as history data in the text file form and convert the table data to the excel form for further refer and doing checking. Moreover, this system has alarm system that when the current temperature is less then or exceed than the normal temperature and critical temperature respectively the alarm will turn on and the LED of the alarm will turn from green color to red color.

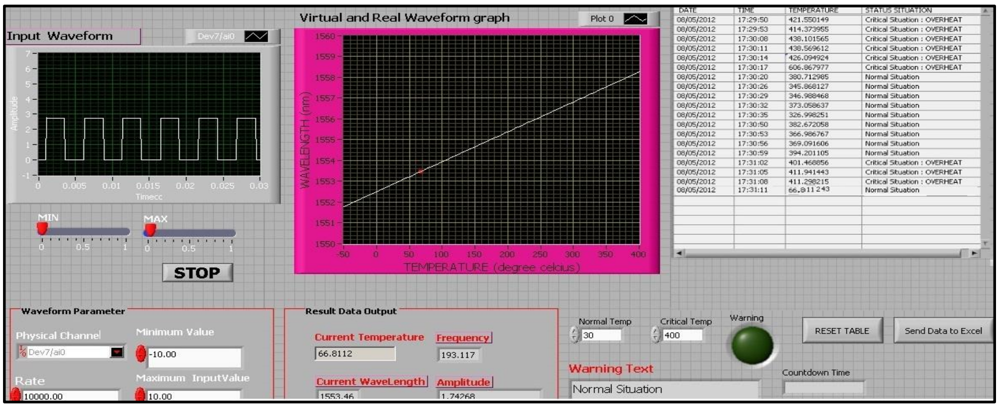

Figure 1.6 Proposed GUI Monitoring Temperature System

Figure 1.6 clearly shows that the current temperature is 66.812°C, the current wavelength is 1553.46nm and the frequency is 193.117Hz. The small dot in red colour shows in the “virtual and real waveform graph” state the current real temperature value and the wavelength value.The current temperature value is in the range of normal temperature and critical temperature.

3. Conclusion

A new approach to designing and optical sensor based on Thin-Flim filter is proposed. In this paper the main objectives of the project are achieved with the development of an optical thermo sensor. This technology is new and promising and can replace the conventional sensing techniques. A sensing system using thin-film optical filter and two wavelengths for measurement is proposed and created. This sensor can probe physical parameter in a localized small area, because it has a small sensing area at the end of an optical fiber. Besides that, it has robust structure, because the optical fiber need not be stripped of its cover coating. The simulation results are obtaining by using the commercial simulating software, OptiSystem ver. 7.0 which the parameter that that affect the performance of the system being considered. The temperature can be calculated from the measurement of the wavelength shift. On an overall, the simulation design specification is successfully achieved in term of wavelength, temperature and power. Moreover, LabView software is used to model both hardware circuit design board and the data information of the simulation system. The graphical user interface (GUI) has been creating in this platform as to monitor the temperature status performance of the real system environment. This GUI system makes cost-effective system and easy to use by the end- user.

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