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Design and Implementation of Communication and Healthcare Sensors

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Abstract

Communication and health care sensors have contributed greatly to patients and medical workers, through first, with the existence of the Covid-19, the hospital beds are unlikely to meet all infected patients, as communication and health care sensors can be used to monitor the patient's vital signs such as (temperature, pressure, Electrocardiogram..) in the hospital wherever the patient is and can be used as an automatic pandemic transmission of an alert signal from the personal servant to the emergency center by monitoring the changes in the vital signs of the individual. Secondly, to connect patients with 24-hour caregivers via the network according to the patient's needs. Thirdly, it can be used to monitor stable chronic patients who have been discharged from hospitals at home as not every patient can afford a home visit by nurses or doctors. An optical fiber sensor for monitoring the vital signs of the patient had been submitted; the temperature had been chosen to be measured. In this research the experimental and simulation by using opt-system program was done. Two different types of optical fiber were chosen as a sensing media; Fiber Bragg Grating FBG (1550nm wavelength, 20nm band width, and 10^{-3} w power) and single mode fiber (SMF), water bath which used to measure the temperature by FBG or SMF sensor for (36–40) C^0. The Optical Spectrum Analyzer (OSA) recorded the input and output spectra. Then the results send as data using Free Space Communication System. The submitted sensors show a very good sensitivity towards temperature, for FBG sensor, the sensitivities 10.5 pm/ C^0 and -8.5 pm/ C^0 while the sensitivity for SMF sensor 5 pm/ C^0 and -5.5 pm/ C^0 for heating and cooling temperature respectively.

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Keywords: FBG, FSO Communication, Opt-system simulation software, SMF.

تصميم وتنفيذ نظام اتصالات ومتحسسات العناية الصحية

سعاد محمد علي ، اسراء كامل الغازي ، الاء ثائر لطيف ، اسيل ابراهيم محمود ، اشواق صالح رشيد

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الخلاصة

ساهمت أجهزة استشعار الاتصالات والرعاية الصحية بشكل كبير في خدمة المرضى والعاملين في المجال الطبي، أولاً، مع وجود كوفيد-19، من غير المرجح أن تلبي أسرة المستشفيات جميع المرضى المصابين، حيث يمكن استخدام أجهزة استشعار الاتصالات والرعاية الصحية لمراقبة العلامات الحيوية للمريض مثل (درجة الحرارة والضغط وتخطيط كهربائية القلب ..) في المستشفى أينما كان المريض ويمكن استخدامها كإرسال تلقائي لإشارة تنبيه من الخادم الشخصي إلى مركز الطوارئ من خلال مراقبة التغيرات في العلامات الحيوية للفرد. ثانيًا، لربط المرضى بمقدمي الرعاية على مدار 24 ساعة عبر الشبكة وفقًا لاحتياجات المريض. ثالثًا، يمكن استخدامه لمراقبة المرضى المزمنين المستقرين الذين خرجوا من المستشفيات في المنزل حيث لا يستطيع كل مريض تحمل تكلفة الزيارة المنزلية من قبل الممرضات أو الأطباء. تم تقديم مستشعر ألياف بصرية لمراقبة العلامات الحيوية للمريض، وتم اختيار درجة الحرارة ليتم قياسها. في هذا البحث تم إجراء التجربة والمحاكاة باستخدام برنامج نظام البصريات. تم اختيار نوعين مختلفين من الألياف البصرية كوسيط استشعار؛ شبكة براج الليفية FBG (طول موجي 1550 نانومتر، وعرض نطاق 20 نانومتر، وقوة 10^{-3} واط) والألياف أحادية الوضع (SMF)، وحمام مائي يستخدم لقياس درجة الحرارة بواسطة مستشعر FBG أو SMF لنطاق (36-40) C^0. سجل محلل الطيف البصري (OSA) أطياف الإدخال والإخراج. ثم تم إرسال النتائج كبيانات باستخدام نظام الاتصالات الفضائية الحرة. تُظهر المستشعرات المقدمة حساسية جيدة جدًا تجاه درجة الحرارة، بالنسبة لمستشعر FBG، كانت الحساسيات 10.5 م/ C^0 و-8.5 م/ C^0 بينما كانت حساسية مستشعر SMF 5 م/ C^0 و-5.5 م/ C^0 لدرجات حرارة التسخين والتبريد على التوالي.

الكلمات المفتاحية: ليف محزز براك، منظومة اتصالات عبر الجو، برنامج محاكاة Opt-system ، ليف بصري احادي النمط.

Introduction:

Having access to health services is one of a person's most basic needs. These days, technology plays a crucial role in improving health. The widespread use of mobile applications and people's desire to be online [1]. Healthcare system consists of users, devices, and servers. Various sensors that are affixed to patients function as tools for monitoring their health, retrieving their medical history, and gathering information. Sensing equipment is linked to the internet, so it can communicate with the server. The Healthcare system's devices have to be easily operated and portable. The server is the most importunes part of a Healthcare system. It includes tools for managing and analyzing health data, working with patients and professionals, and serving as a service provider. [2]. Medical body-area network sensors collect data before transmitting it to the base station, where doctors and caregivers review it and take necessary actions. These networks utilize two types of sensor devices: internal and external. Internal devices include implanted sensors or ingestible capsules, such as core temperature sensors, as well as implanted chips used to monitor conditions like paralysis and Parkinson's disease, and endoscope sensors. External sensors are wearable and detachable devices, such as pulse oximeters, electrocardiographs, and body temperature sensors. [3]. The development of smart sensors for medical applications is gaining more attention due to the growing number of patients who need continuous monitoring of these physiological parameters. Optical fiber-based sensors have gained special attention due to their many benefits over traditional electrical sensors, including their cylindrical geometry, light weight, small size, resistance to environmental factors, high sensitivity, size compression, ability to sense remotely, and immunity to electromagnetic interference [4][5]. Optical fiber sensors possess distinct attributes, including low production costs, small and flexible designs, chemical inertness, and the capacity to distribute and sense multiple parameters on a single fiber, in addition to the features mentioned above [6]. As demonstrated in Fig.1, responsive health monitoring systems use metrics such as heart rate, body temperature, blood pressure, oxygen saturation, blood glucose, blood sugar, Electroencephalogram and Electrocardiogram to continuously monitor and analyze several biological data points in order to identify medical abnormalities early on [7].

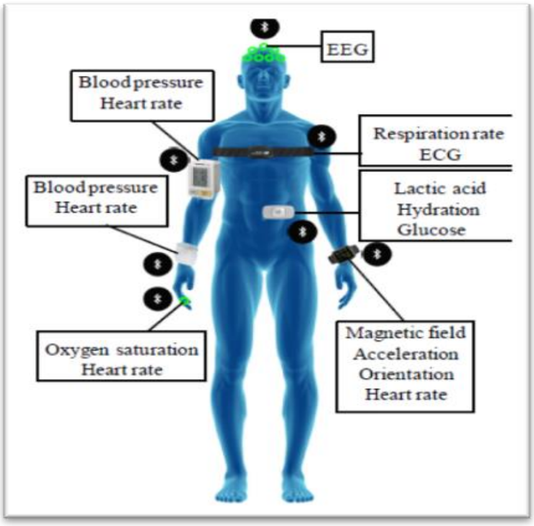


Fig. (1): Different biomedical sensors [7].

Health monitoring systems are one of the most notable applications of IoT. Many types of designs and patterns have already been implemented to monitor a patient's health condition through Internet of Things (IoT) [8].

In pandemics, it is essential to isolate patients to limit the spread of infection, but doctors still need to monitor their health regularly, which exposes them to risk. To solve this issue, a remote health monitoring system using Internet of Things (IoT) technology was designed. The system measures vital signs such as heart rate, temperature, oxygen level, and blood pressure, and sends the data via Wi-Fi to the (Thing Speak Platform TSP). The system is based on a Node MCU unit and can alert doctors in case of any abnormal health condition in the patient [9] [10]. Fiber Bragg Gratings FBG in sensing technology has drawn interest from a growing number of industries worldwide recently, which has accelerated the development and use of optical sensors, particularly those used for strain and temperature monitoring [11]. FBG has several benefits, including a long lifespan and comparatively small size. Additionally, it is inexpensive to produce, lightweight, capable of multiplexing, self-referencing with a linear response, durable, immune to electromagnetic interference, and easy to install. [12] Particular kind of distributed Bragg reflectors, the FBGs transmit certain wavelengths and reflect others. In order to achieve this idea, the refractive index of optical fiber is changed as a periodic changing of the core, creating a dielectric mirror that can reflect a specific wavelength. Thus, as shown in Figure (2), the FBG could be utilized to block the particular wavelength [13].

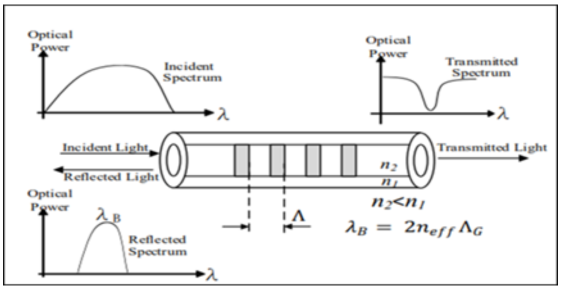


Fig. (2): Fiber Bragg grating (FBG) principle [13].

The principle of working of the FBG, as function of parameters by equation (1), is the Bragg wavelength (λ_B) shifting which reflected from the grating period (Λ) and the fiber core's effective refractive index (n_{eff}) are effective [13] [14] [15].

$$\lambda_B = 2n_{eff}\,\Lambda \qquad \ldots\ldots \quad (1)$$

Thus, the two factors affecting the Bragg wavelength change are either variations in the grating period or the effective refractive index of the optical fiber core. Strain and temperature-related physical grating changes can be detected by the

Bragg wavelength [15]. A wavelength shift is produced by the simultaneous changes in the grating spacing and effective refractive index brought about by thermal expansion in the FBG. The fractional Bragg wavelength shift for a temperature change of ΔT can be expressed as follows:

$$\Delta\lambda_B/\lambda_0 = (\alpha+\xi)\,\Delta T \qquad \text{..... (2)}$$

Where ($\Delta\lambda_B$) wavelength difference compared to original Bragg wavelength (λ_0) and (α) is thermo-optic coefficients, (ξ) is thermal coefficient [16].

Previous studies on this topic include, the research addresses the design of a smart system for remote monitoring of sleep disorders using FBG (Fiber Bragg Grating) sensors embedded in a smart vest. Biometric data from the patient is transmitted via a highly efficient free-floating optical (FSO) system, allowing it to be transmitted wirelessly to the processing unit. The system focuses on measuring variables such as respiratory rate and body movement during sleep. The solution features low power consumption and high accuracy in detecting abnormal sleep patterns. This system represents an important step toward improving home healthcare using modern fiber optic and communication technologies [17].

In (2023) the study presents the design and implementation of a remote healthcare monitoring system using wearable sensors to measure vital signs such as heart rate and blood pressure. The system aims to improve patient care, especially for the elderly and those with chronic illnesses, through continuous monitoring. Data is transmitted to a cloud server for analysis and alerts healthcare providers in case of critical changes. The system demonstrated high efficiency in early detection of abnormal health conditions. The researchers concluded that the system enhances healthcare effectiveness while saving time and cost [18].

In (2022) the study presents the design of a remote medical monitoring system based on Internet of Things (IoT) technologies to measure vital signs such as ECG and body temperature. The system aims to enhance continuous healthcare for patients, especially in remote or resource-limited areas. It uses accurate sensors to transmit real-time data to a monitoring interface. The prototype was successfully implemented and tested, showing its effectiveness in tracking health conditions. The researchers concluded that such systems support the shift toward smart and efficient healthcare [19].

The study presents the design and implementation of a real-time health care monitoring system using Internet of Things (IoT) technologies. The system relies on medical sensors to measure temperature, heart rate, and blood oxygen levels. Data is collected by a microcontroller unit (Arduino Uno) and displayed via a graphical interface using Visual Basic. Once the data is gathered, it is transmitted online to healthcare professionals for remote patient evaluation. The system showed high effectiveness in improving continuous healthcare and reducing the need for in-person visits [20].

Simulation Schematic of Healthcare Sensors system

This work will design a simulation system using Opt-system software 7 to sense human body temperature and vital signs, as illustrated in Figure(3).

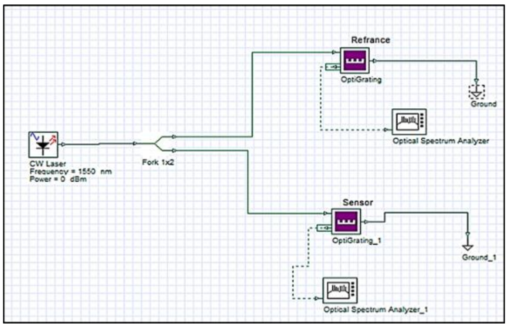


Fig. (3): Simulation design of FBG temperature sensor.

The system consist of CW laser diode at 1550nm wavelength (band width 20nm and wavelength (1540-1560) nm with power 10^{-3}W) connects with two FBG sensors, the first FBG sensor which represent as reference at human temperature degree ($37C^0$), the second FBG sensor which contact with opt-grating program to changing in temperature degrees from (36- 40) $C^0$and compere with human temperature degree ($37C^0$) reference. The reflected Bragg wavelength observed by OSA (Optical Spectrum Analyzer) as shown in Figure (4).

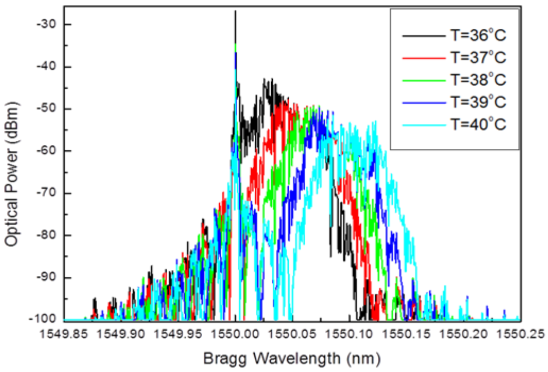


Fig. (4): Received signals of FBG Temperature sensor.

After receiving the parameters (received signals) from the patient, they are sent to the hospital or the doctor who monitors the patient's condition by using free space optical communication (FSO) system, as in the following simulation setup Figure (5).

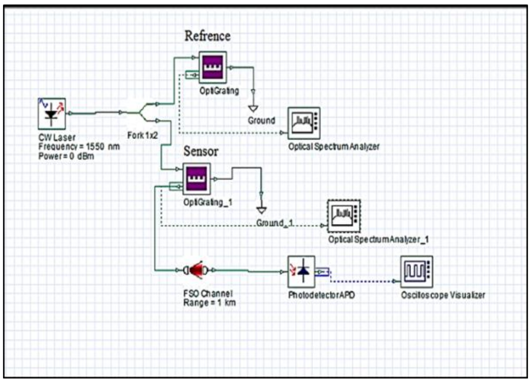


Fig. (5): Simulation setup of Temperature sensor with sent data.

The output signals (received signals) represented in Figure (6).

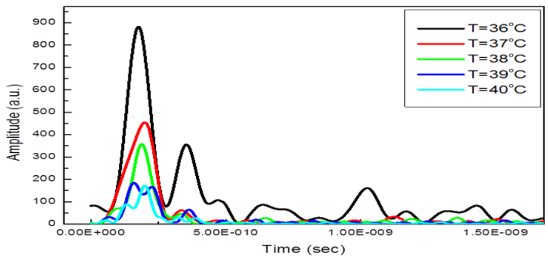


Fig. (6): Reflected FBG spectra of Temperature sensor.

Reflected FBG spectra at up temperature $40C^0$ and low temperature $36C^0$ represented in Figure (7).

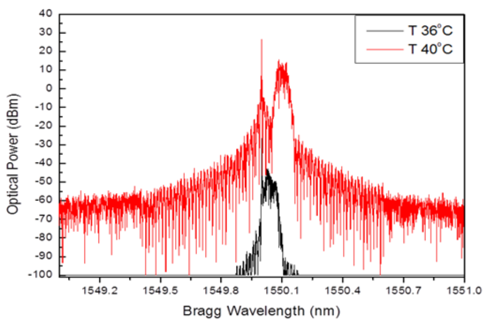


Fig. (7): Reflected FBG spectra at up temperature 40 C0 and low temperature 36C0.

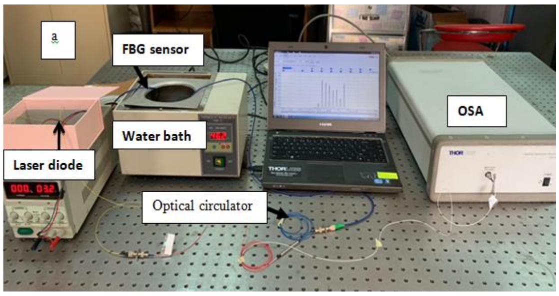
Experimental and setup

Two types of optical fiber sensors were tested in the experimental configuration of a healthcare sensor system, which is used to measure human temperature in degrees Celsius between (36 and 40) C^0:

1. Sensor for Fiber Bragg Grating (FBG).

2. A sensor using single-mode fiber (SMF).

The FBG sensor system consists of an optical circulator that connects the FBG to a CW laser diode (1550nm wavelength, 20nm band width, and 10^{-3} w power). The temperature in the water bath is adjusted by an FBG sensor, which ranges from (36–40) C^0. The Optical Spectrum Analyzer (OSA, Thorlabs 203, wavelength (1000–2500) nm with 0.1nm resolution) recorded the input and output spectra., as shown in Figures 8 (a, b), which represent the real design of a Healthcare Sensors system in laboratory and schematic design for FBG sensor respectively. This experiment investigated the effects of temperature changes (raised or lowered) on the FBG wavelength.



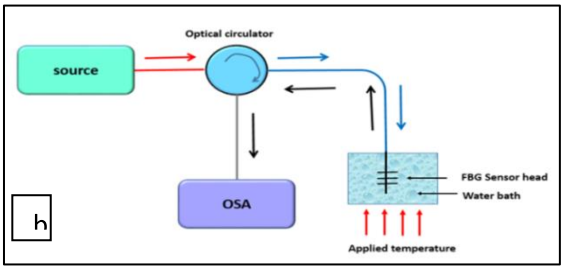


Fig. (8): (a) photograph, (b) Schematic of FBG temperature sensor.

The experimental set-up of a Healthcare Sensors system repeated by using Single Mode Fiber (SMF) sensor, as shown in Figure 9 (a, b).

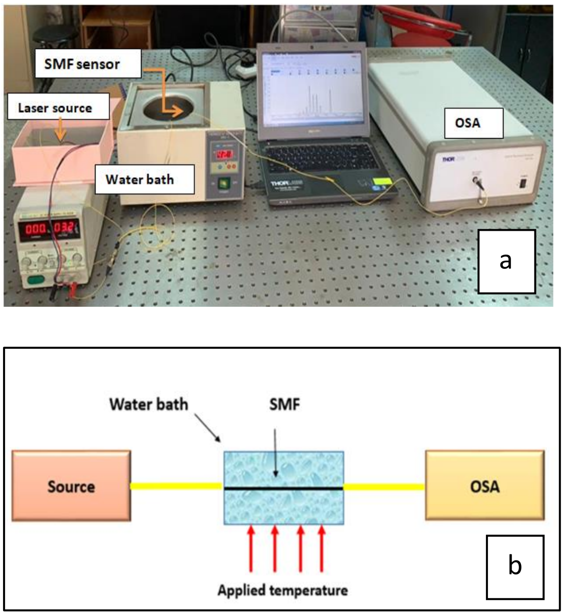
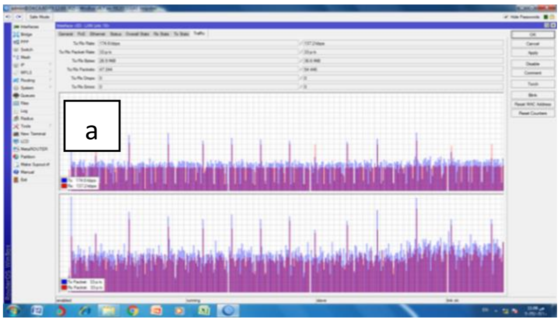


Fig. (9): (a) photograph, (b) Schematic of SMF temperature sensor.

The measured human temperature is transmitted via the free space data to the free space optical communication system (FSO) as shown in figure 10 (a, b).



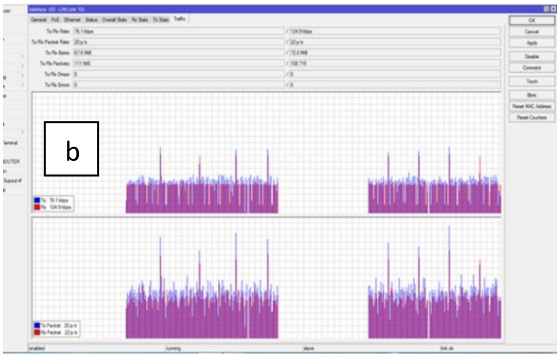


Fig.10 (a, b): Transmitted and received signals by FSO communication system.

In health care sensors to monitor the patient's condition remotely, information about the patient's condition is constantly collected and sent to the hospital or the supervising doctor via communications systems over the air, and this data is sent via the Internet or Wi-Fi network to systems in the hospital or specialized health center, as in the figure above.

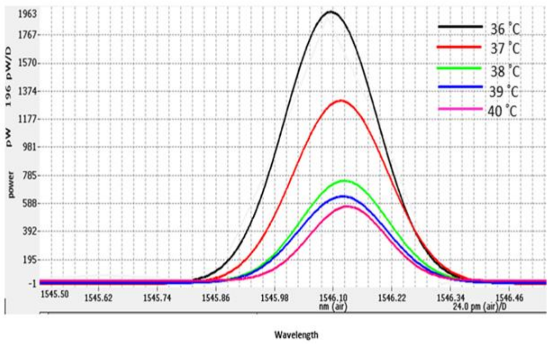


Fig.11: Reflected FBG spectra due for increasing temperatures.

Result and Discussions

The temperature sensor for measuring human body temperature was the FBG sensor, which has a Bragg wavelength of 1550 nm. of (36-40) C^0 with increasing and decreasing temperature. The reflected spectrum (Bragg wavelength) is red shift due to the effective refractive index and spacing between the gratings varies depending on the Equation (2) as shown in the Figure (11).

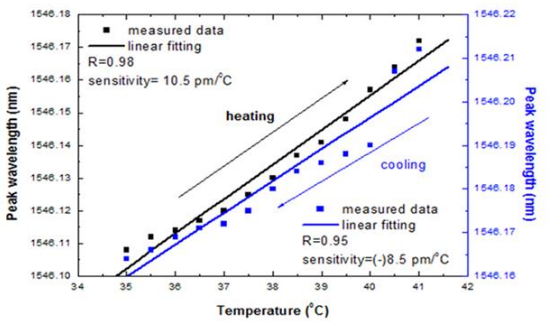


Fig. 12: Linear relationship for heating and cooling temperatures for FBG sensor.

The sensor's high linearity and roughly equal heating and cooling sensitivity are shown in Figure (12), 10.5 pm/C^0 and -8.5 pm/C^0, where the sign (+ ve) refer to red shift and (– ve) sign refer to blue shift. The sensor performance is also tested in case of decreasing temperature to insure the linearity of the sensor behavior. Figure (13) shows the relation between the shifting in peak power in case of increasing (heating) temperature (black line) and decreasing of temperature cooling (blue line). As was previously mentioned, the applied temperature caused attenuation in the peak power.

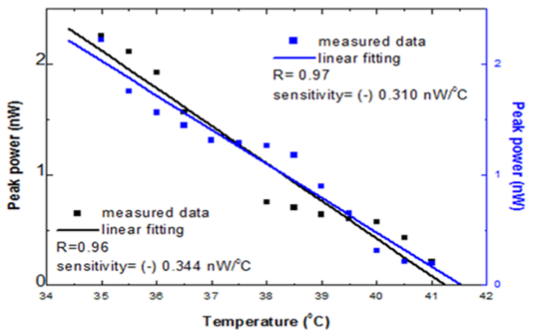


Fig. 13: The relation between the attenuation in the peak power and heating temperature of FBG sensor.

The linear relationship between temperature and peak power yields the sensitivity; in this case, the sensitivities were equal (-0.310nW/C^0) and (- 0.344 nW/C^0) the temperature for heating and cooling respectively. Single Mode Fiber (SMF) sensor with diameter 125 micrometer used as a human temperature sensor with range (36-40) C^0. Below figure shows the transmission spectrum of SMF sensor due to change the temperature:

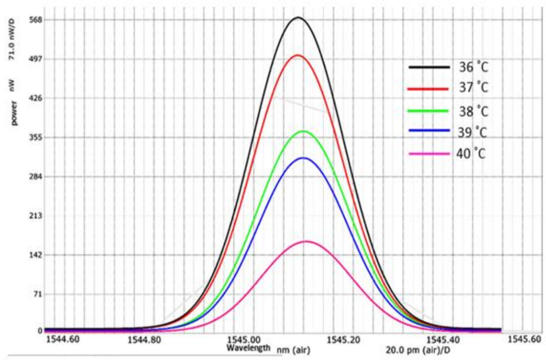


Fig.14: The SMF transmission spectrum as a result of heating temperatures.

Attenuation of the peak power coincided with the wavelength shifting towards the red region. Due to a change in the refractive index of the fiber core material as a result of the rise or fall in body temperature the same study done with FBG sensor is done in SMF sensor; to study the performance of the sensor when the temperature is decease (cooling). Figure (15) depicts the relationship between temperature and wavelength shifting, and the sensor exhibits high linearity and sensitivity in this regard. The linear relationship between temperature and wavelength was used to determine the sensitivity. The sensitivity for increasing and decreasing temperature was 5 pm/ C^0 and -5.5pm/ C^0 respectively.

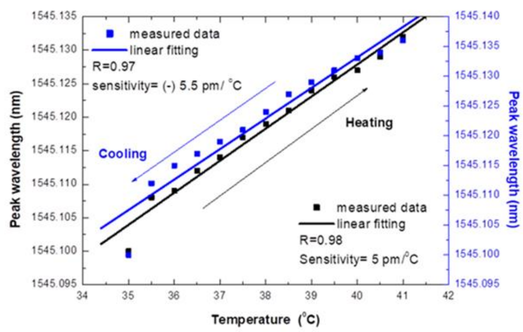


Fig. 15: Relationship for heating and cooling temperatures for SMF sensor.

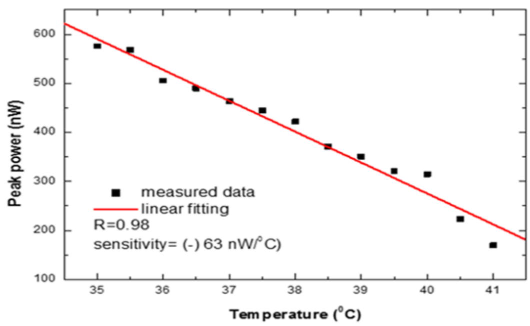


Fig. 16: The relationship between the peak power and the heating temperature of SMF sensor.

The relationship between peak power and temperature is depicted in Figure (16) in the event that the behavior was random during cooling. The applied temperature was the cause of the peak power attenuation. The sensitivity is equal to (-63nW/C^0) and was determined by analyzing the linear relationship between the applied temperature and peak power.

Conclusions:

A healthcare sensor system was introduced in this work for applications related to connected health and safety. With wearable sensors attached to the body, the system can monitor a patient's vital signs, including their body temperature. This data is then used to form a valuable report that the system operator and staff can use to monitor the patient's safety and health. The suggested healthcare sensor system served two functions in the health system. device in free space, which gathers user health data via the sensors and transmits it to the e-Health server. The findings for two sensors demonstrate good linearity and sensitivity; the FBG sensor, for example, has roughly equal heating and cooling sensitivities of (10.5pm/C^0) and (-8.5pm/C^0). The SMF sensor's sensitivity for increasing and decreasing temperature was (5pm/C^0) and (-5.5pm/C^0), respectively; the sensitivity is equal to (-63nW/C^0). The sensitivity was derived from the drive relationship between peak power and temperature. The sensitivities were equal to (-0.310 nW/C^0) and (-0.344nW/C^0) for heating and cooling temperatures, respectively. As a result, we observed that the FBG sensor's sensitivity was higher than the SMF sensor's.

Conflict of Interest:

The authors declared no conflict of interest.

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