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# Designing and Constructing the Strain Sensor Using Microbend Multimode Fiber

***Samar Younis AL-Dabagh*[1]** ***Nahla A.ALjaber*[2]** ***Ghasaq O. AL-Hassnawy*[1]**

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## Abstract:

The microbend sensor is designed to experience a light loss when force is applied to the sensor. The periodic microbends cause propagating light to couple into higher order modes, the existing higher order modes become unguided modes**.** Three models of deform cells are fabricated at (3, 5, 8) mm pitchand tested by using MMF and laser source at 850 nm. The maximum output power of (8, 5, 3)mm model is (3, 2.7, 2.55)nW respectively at applied force 5N and the minimum value is (1.9, 1.65, 1.5)nW respectively at 60N.The strain is calculated at different microbend cells ,and the best sensitivity of this sensor for cell 8mm is equal to 0.6nW/N.

**Keywords**: Microbend Sensor, Strain Sensor, Fiber Sensor, Evanescent Wave, Evanescent Wave for Sensing Application

## Introduction:

The term commonly used for strain sensor is strain gauge. A strain gauge is an instrument used to measure the linear distortion [mechanical surface strain] occuring in a material through loading in addition to their essential use for measuring strain as thus, strain gauges are also used for measuring other physical amount such as pressure, force, displacement, twine, and so on by using them as sensors in other measuring systems(1). Sensors are devices which transform physical or chemical amount into electrical signals appropriate to use. Optical Sensors are used in many researches, and trade applications today. Sensor system is a sensor which mixes some kinds of signal conversion [analog or digital]. The sensor is inclusive in the sensor system and it is the first dribble to input the datum measured(2). A fiber optics sensor is a sensor that uses optical fiber as the sensing element (intrinsic) or as a guiding medium for carrying signal from light source to a box for processing the signal and then carry processed signal to detector (3). Optical fiber strain sensors have setup great interest in the sensor community due to their built-in size and ability to work in a tough environment.

[1] Department of Physics, College of Science for Women, University of Baghdad, Baghdad, Iraq.
[2] Ministry of Science Technology, Laser and optoelectronic center, Bagdad, Iraq.
[*]Corresponding author: nora.omran@yahoo.com

Most present optical fiber sensors are silica-based optical fiber generally which have a large stiffness and can only sustain maximum strains of about 3-6%. In general ,silica-based optical fiber strain sensors are only safe up to around 4% strain except when special planning procedures are followed (4).Impermanent field absorption spectroscopy is a robust well-established laboratory technique for strain disclosure in optical fiber(5).Today researchers use fiber bragg grating (FBG) strain sensor rather than conventional optical fiber sensor because very high strain**,** small size, lighter weight, high immune to electromagnetic, high long term stability, good corrosion resistance, can be used at very high temperatures 600°C, very low magnetic field interactions and breeze of installation (6,7).

## Materials and Methods:

### Mathematical Model and Experimental Work of Optical Fiber Strain Sensor:

***1-Mathematical model***

$\mathcal{E}=\mathbf{\Delta p}d/2Yt$ …(1)

When $\boldsymbol{\mathcal{E}}$ is Hoop strain, $\mathbf{\Delta p}$ represents an applied pressure, **Y** young's modulus $=5.4*10^{10}$ $N/m^2$, **t**(thickness of the spacer material between the deformer plates) as show in Fig. 1, **d** fiber radius =0.001m

$\mathbf{\Delta P}=\Delta F/A$ …(2)

Where **ΔF** is the applied force, **A** is the area $=0.0003m^2$

$\Delta p_o = S\ \Delta F(K_f + AY/t)^{-1}$ …(3)

Where :

$K_f = 3\pi Y d^4 \eta / \Lambda^3$ …(4)

Where $\Delta p_o$ Change in power, S is the sensitivity, $\Lambda$ is mechanical periodicity, the $k_f$ is the effective spring constant of the optical fiber and $\eta$ is the number of bent intervals(8,9).The inversely relationship between applied force and output power .

*AY /t=neglect because is very small*

$\Delta p_o = S \mathbf{\Delta p} A\ K_f^{-1}$

$\mathbf{\Delta p} = \Delta p_o * Kf / S\ * A$ …(5)

Equation (5)is compensated in(1)

$\varepsilon = \Delta p_o * K_f / S * A * d / 2Yt$

$\varepsilon = \Delta p_o * K_f * d / 2Yt\ S * A$ … (6)

$$S = \frac{P_{max} - P_{min}}{F_{max} - F_{min}}$$

## *2-Experimental work*

The force(5-60)N is applied at the corrugated microbend cell is shown in Fig.1 where the multimode fiber (MMF) is sandwiched between these two plates .The fiber is still bending even remove the applied force. The change in the optical power ($\Delta p_o$) before and after applying the force is measured. The power loss of microbend and strain are calculated. The experimental work setup is shown in Fig. 2.

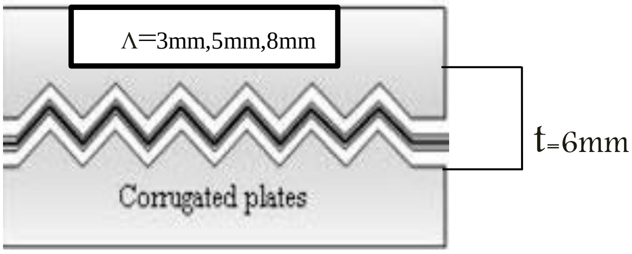


**Figure 1. The geometric design of microbend cell**

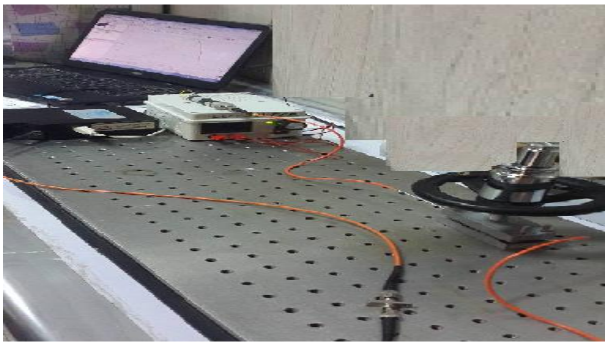

**Figure 2. The photograph of the experimental setup**

## Results and Discussion:

Three microbend cells(3, 5, 8)mm are tested by using MMF. The laser use with wavelength 850nm as transmitter and OSA (optical spectrum analyzer)as detector. Fig.3 were illustrates the transmitted spectrum of first the cell (Λ =3mm).It is shown that the intensity is decreases with increasing the applied force as a result of increasing the strain. When the force is placed on the optical fiber, a curvature will occur that causes the change of the numerical aperture and thus the wave will fade the increase linearly by increasing the applied force.

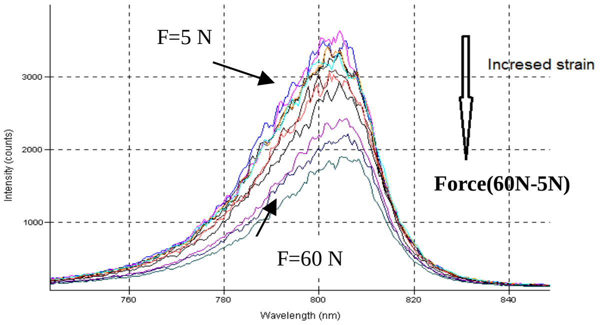


**Figure 3. The Transmitted Spectrum of 3 mm Microbend Cell.**

The result is the same for the second and third cells **Λ**=5mm and 8 mm as shown in Fig.4and 5 respectively.

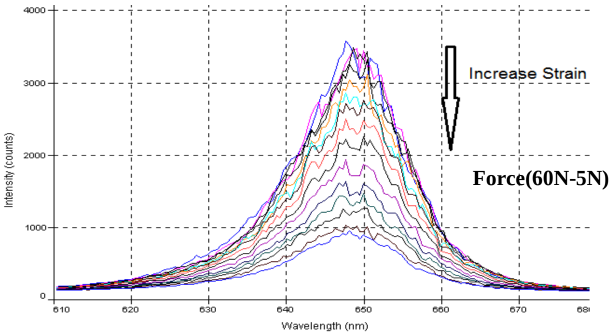


**Figure 4. The Transmitted Spectrum of 5 mm Microbend Cell**

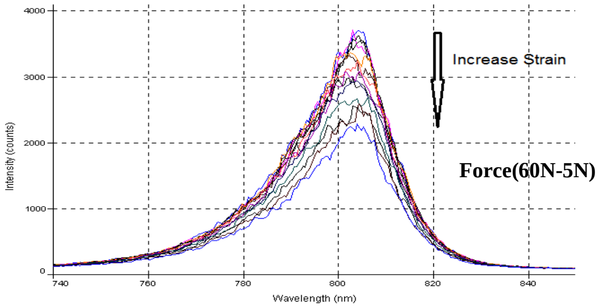


**Figure 5. The Transmitted Spectrum of 8 mm Microbend Cell.**

From Figs. 3, 4 and 5 it can be shown that the best sensor is obtain when using the pitch cell equal 3 mm where any change in the applied force directly translated in to a change in the transmitted light signal through fiber optics.

The output power of transmitted as a function of the applied force is shown in Fig.6 for three microbend cells models .From this Figure, the output power decreases with increasing applied force. The output power of 8mm microbend cell is higher than the output power of 5mm, 3mm models. The maximum output power of 8mm model is 3nW at the applied force 5N and the minimum value is 1.9nW at 60 N, then the maximum power for the 5mm model equal to 2.7nW at the applied force 5N at and the minimum value is 1.65nW also at 60N .The maximum power for 3mm model equal 2.55nW at the applied force 5N at and minimum value is 1.5nW also at 60N.

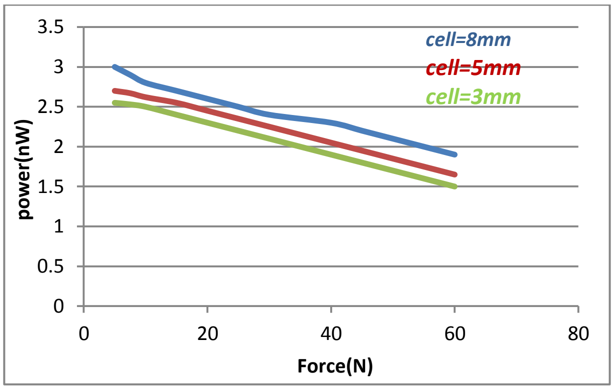


**Figure 6. The Relation between Output Power and the Applied Force.**

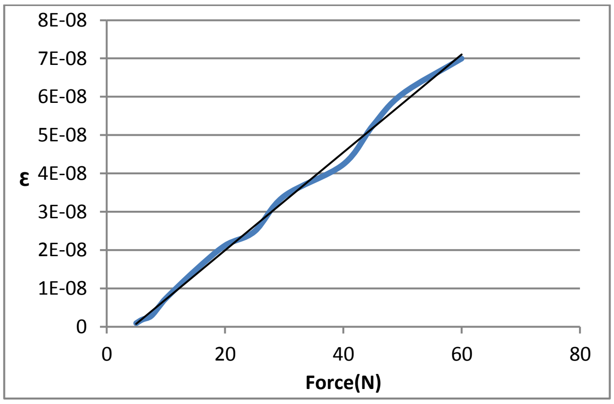


**Figure 7. The Strain via Applied Force for 3mm Cell.**

According to equation (6) the strain coefficient is calculated. The strain coefficient at various applied force is shown in Figs. 7, 8 and 9 for 3, 5, 8 mm cell respectively .

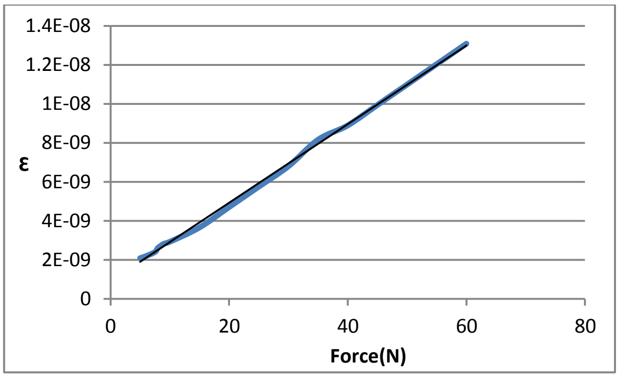


**Figure 8. The strain via applied force for 5mmcell**

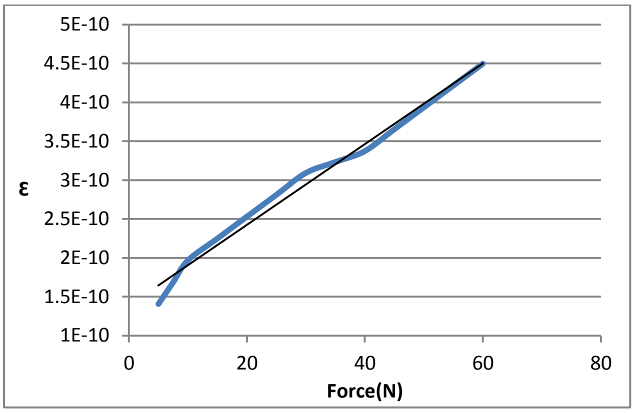


**Figure 9. The Strain via Applied Force for 8mm Cell**

Figure 7 shows the relation between the strain and the applied force for cell (3 mm) at λ=850nm by using fiber MM .The strain is proportional to the force directly. Because of this strain, which occurs in the fiber due to the effect of the applied force .When bending the fiber, the transmission of light change due to the change of the accepting angle and NA. The parts of modes are escape a loss of output power occurs due to evanescent field. The same effects appear in the other cell (5mm and 8 mm) as shown in Fig. 8 and 9 respectively.

## Conclusion:

The ability of strain fiber sensor to monitor strain at multiple locations simultaneously presents a big advantage over present electronic strain gauges. In the present research study sensitivity of strain cells by using micro bend three designs. The best sensitivity is equal to (0.6nW/N) for λ=850 nmat three (3, 5, 8)mmcells.

## Conflicts of Interest: None.

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# تصميم وبناء متحسس الإجهاد باستخدام خلية الانحناءات الدقيقة للألياف البصرية متعددة الأنماط


**سمر يونس الدباغ[1]** **نهلة عبد الجبار[2]** **غسق عمران الحسناوي[1]**

[1]قسم الفيزياء، كلية العلوم للبنات، جامعه بغداد، بغداد، العراق.
[2] وزارة العلوم والتكنولوجيا، دائرة بحوث المواد، بغداد، العراق.



**الخلاصة:**

تم تصميم متحسس الانحناءات المايكروية لاحتساب خسارة الضوء عند تسليط قوة على متحسس..حيث تسببت الانحناءات المتكررة انتشار الضوء الى الأنماط أعلى. الأنماط الحالية تصبح انماط غير مرشدة .صنعت ثلاث نماذج من الخلايا الانحناءات المايكروية بدرجات تسنن (3,5,8)mm وأختبرت بأستخدام ليف متعددة النمط ومصدر ليزربطول موجي (850 nm).حيث اعظم قدرة للخلايا (3,5,8mm)هي (2.55, 2.7, 3)nWعلى التوالي عند تسليط قوة مقدارها 5N واقل قدرة تكون (1.9, 1.65, 1.5)nWعلى التوالي عند تسليط قوة مقدارها 60N. الاستطالة من مختلف خلاياالانحناءات المايكروية تم حسابها، أن أفضل تحسسيه للخلية 8mm تساوي 0.6nW/N.



**الكلمات المفتاحية:** متحسس الانحناء المايكروي، متحسس الإجهاد، متحسس الألياف، موجة متلاشية، موجة متلاشية لتطبيقات التحسسية .