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RESEARCH ARTICLE

FORCE PRESSURE SENSOR BASED ON MICROBEND OPTICAL FIBER

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ABSTRACT

The fiber optic sensors are small, electrically isolated and immune to electromagnetic field, they are an correct choice to detect the vibration ,cracks on building and environment factors Practically, microbend fiber optic pressure force sensors are limited to intensity-modulated and interferometric (or phase-modulated) methodologies. The main purpose of this project we propose an analyzing of the response of a force pressure optical fiber sensor .The relation between the output power and the applied force pressure show that an optical fiber sensor with these design can covenanting allow the measuring the force/stress applied to a mechanical structure or which it is linked, by optimizing the uses of appropriate materials for constituting the sensor support. In this work ,the transmitted beam power through the optical fiber due to force pressure on optical fiber to determine the pressure sensitivity .A multimode optical fiber (50,125) is pressed by using force in the range (5-50) N at (1) m multimode fiber. The fiber is passed through microbend cell made from Al material at dimension (3.2 × 7.5) cm.

INTRODUCTION

In fiber optic sensor the heart of the sensor is an optical fiber. By using optical fiber sensing devices one can measure or monitor different physical and chemical parameters in terms of one of the principal parameters that describe the light beams [3]. These principal parameters include light intensity, phase, polarization and wavelength. An optical fiber sensor it is a device that converts light rays in to electronic signals. Similar to a photo resistor, fiber optic sensors (FOS) work like other electrical sensors except that the FOS uses a glass fiber instead of copper wire and light instead of electricity. It measures the physical quantity of light and translates by the instrument. One of the features of an optical sensor is its ability to measure the changes from one or more light beams. This change is most often based around alterations to the intensity of the light. Optical sensors can work either on the single point method or through a distribution of points. Through the single point method, a sole phase change is needed to activate the sensor .In terms of the distribution concept; the sensor is reactive along series of sensors or single fiber optic. Optical fibers are also attractive for other applications such as in sensing, control and instrumentation. In the simplest form, an optical fiber sensor is composed of a light source, optical fiber; sensing element and a detector [11,12].

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Microbending Sensor

An optical microbending sensor is built to create periodical microbendings of optical fiber at a short part of it. The sensor structure is simple; can be created by a pair of deformation plates which cause bends of fiber in a regular pattern is shown in Figure (1) [36]. Sensing region are consist of two corrugated plates. The fiber is pressed between these plates by applying different forces to the top plate. Optical fiber passes through these corrugated plates. Both ends of the fiber inside the sensor are relaxed to keep away elastic factors of the fiber. Λ is the mechanical periodicity (deformer tooth spacing), *ls* is the corrugation size (thickness of the spacer material between the deformer plates) and cylindrical grooves are the corrugations (bends). When an optical fiber is bent, it causes the output intensity to decrease due to the loss at the bend. Therefore, when an external force is applied to the apparatus shown in Figure (1), the output intensity will decrease. This output intensity is inversely related to the applied force. Because light is entirely confined to the fiber, the possibility of environmental contamination is eliminated. Temperature, acceleration, strain, displacement, vibration, and pressure are natural parameters to be measured using this technique [37,38]. Microbend loss occurs when small bend in the core-cladding interface of the optical fiber causes the propagating light intensity to be coupled out of the core, for purpose of microbend sensor, microbend losses are in curried mechanically, when an external force caused the optical fiber to be squeezed between corrugated plate.

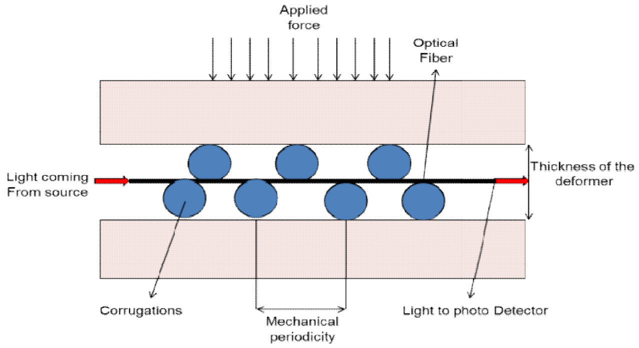

Figure 1. Geometry of microbending sensor

The general equation used in modeling and designing microbend Sensor's eq (1). The change in the light transmission (ΔT), propagation through a microbend sensor is a function of a constant (D) and the environmental change (ΔE), in addition, (ΔE) results in the deformation plates applying a force (ΔF) to the bend fiber, theory causing a deformation of the fiber by an amount (ΔX),the deformation is often expressed as the product of the environmental change time the constant or

$$\Delta X = D\Delta E \quad (1)$$

$$\Delta T = (\Delta T/ \Delta X)\ D.\Delta E \quad (2)$$

[39] Equation (2) written in the terms of the force ΔF applied to the bent fiber becomes

$$\Delta T = \left(\frac{\Delta T}{\Delta X}\right)\Delta F\left(\frac{Kf + AsYs}{Ls}\right)^{-1} \quad (3)$$

$$\Delta T = (\Delta T/\Delta X)\ \Delta P_A\ (Kf + AsYs/Ls) \quad (4)$$

Where the change in pressure is denoted by (ΔP), pressure area (A_p). Therefore if ($\frac{A_S Y_S}{L_S}$) so small such that the effective conformity of the pressure sensor is deformation by that of the bent fiber, then equation (4) reduced in equation (5)

Where

$$KF^{-1} = \frac{\Lambda^2}{2\pi Y d^4 \eta} \quad (5)$$

Represent (d) fiber diameter, (η) number of bend. When designing a microbend fiber optical sensor, equation (5) is an important parameter, the term (Kf^{-1}) is recognized as the effective spring constant for the assembled microbend sensor. The effective spring constant is a function of the deformation tooth spacing (Λ), the force constant involved with changing the length of the deformer spacers. The coefficient ΔT/ΔX, which relates the change in transmission to the change in fiber deformation amplitude, depends on the modal properties of the fiber. The change in optical transmission through the bent fiber results in a change in optical energy incident on the photodetector. The change in the photodetector output signal is thus used to detect the original environmental perturbation ΔE. Depending on the construction of the deformer, various environmental parameters can in principle be sensed.

Experimental work

The light may be lost from an optical fiber when the bend radius of the fiber exceeds the critical angle necessary to confine the light to the core area and there is leakage into the cladding. Local microbending of the fiber can cause this to occur. As a result intensity modulation of light propagating through an optical fiber will occur. The schematic block diagram of microbend optical fiber sensor system is shown in the Figure (2). A typical layout of this type of sensor consisting of a light source, a section of optical fiber positioned in a microbend transducer designed to intensity-modulate light in response to an environmental effect, and a detector. In some cases the microbend transducer can be implemented by using special fiber cabling or optical fiber that is simply optimized to be sensitive to microbending loss. The photograph picture of the experimental work is shown in Figure (3).

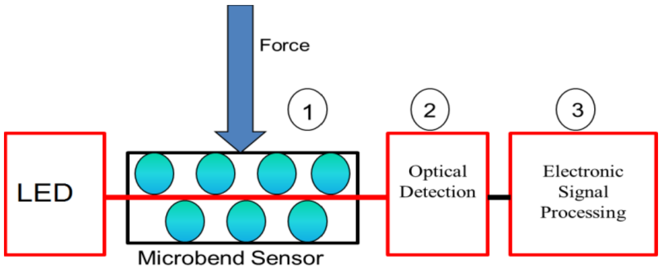

Figure 2. The schematic diagram of experimental work

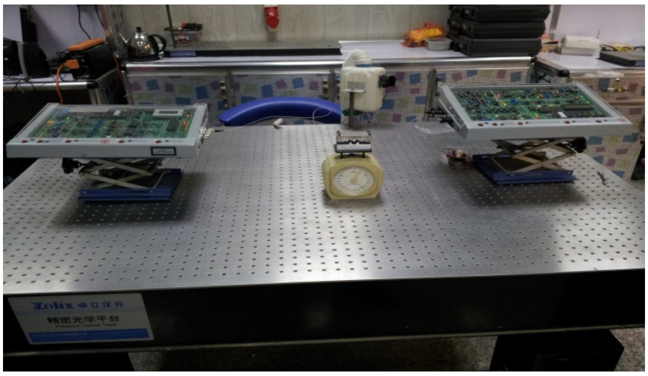

Figure 3. Photograph picture of the experimental work

The experimental setup is consists of an optical source (LED, Light emitting diode, optical fiber, sensing cell or modulator element, an optical detector (photodiode), optical spectrum analyzer and processing electronics.

Light source

The light emitting diode is used as feeding source for fiber optic cable at wavelength 592nm, orange color. The power is equal to (4.5 μW). The package of transmitter LED is proved from Promax company at model Fiber optic Communications system Emitter EF-970/E is shown in Figure (4). This package contains the driver circuit of light emitting diode at different wavelength. The power of LED is controlled by driver current circuit which appears in digital screen.

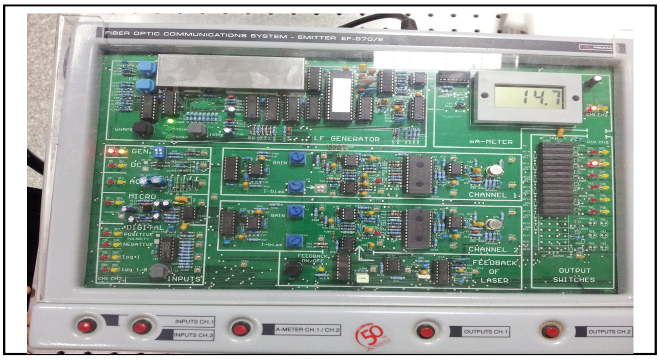

Figure 4. The photograph of the transmitter Kit

Microbend deformer cells

The microbend sensor employs a fiber between two ridged plates with an optimum periodicity depending upon the modal properties of the fiber. (This periodicity is typically in the millimeter range). A displacement of the plates changes the amplitude of the bends resulting in intensity modulation. The schematic diagram of geometry design of a sensing region for the microbend sensor is shown in Figure (5) and the photograph picture is shown in Figure (6). The sensing region consists of two modulation cells. The cell is designed and constructed at two corrugated plates. It is made from Al material block ,which is operated by cutter wire technique. The microbend cells dimensions are (3.2 cm * 7.5cm), mechanical periodic Λ equal (5mm), l_s equal(5 & 6 mm).

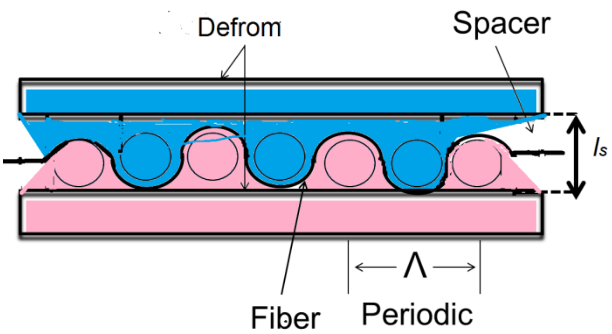

Figure 5. The geometric design of microbend cell

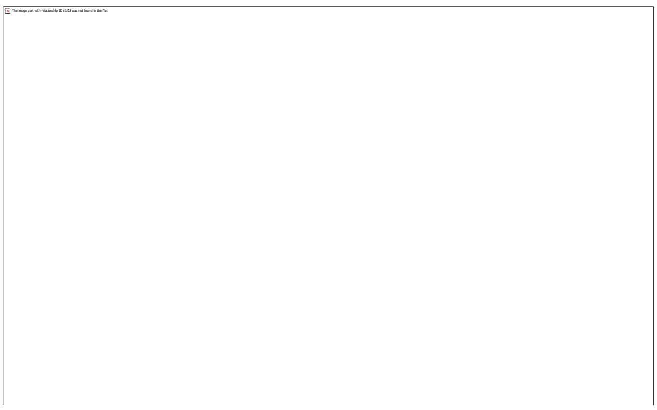

Figure 6. The photograph picture of microbend cells

The receiver

This unit is used to drive the detectors at different spectrum range. The power is measured from output fiber. This kit is provided from Promax company at model Fiber optic communications system-Receiver EF-970/R. which is shown in Figure (7). This kit includes the digital screen to display the output power in watt & dB and four input terminal each terminal for the one wavelength. It is adjustable to select which terminal input power according the testing wavelength.

Figure 7. The photograph picture of receiver Kit

RESULTS AND DISCUSSION

The wavelength λ=592nm is transmitted through MMF, where this fiber is passing through microbend cell at 5 mm or 6 mm. The relation between applied pressure force and the output power is shown in Fig (8). From this figure the increase of applied force at range from 5N to 50N caused to decreased the output power. The reference power means no applied force on two microbend cells is 4.5 µw. The output power from (5mm) microbend cell change from 4.5µw to 3.3µw at the force range from 0N to 50 N at step 5 N and the output power from the second microbend cell (6mm) ranges from 4.5µw to 2.6 µw at the same range of applied force. This figure shows the output power at 6mm microbend cell is less than 5mm microbend cell because of the microbend cell 6 mm model is greater bend fiber than the 5 mm model, that means increased the bend losses. The calculated output power of two model of microbend cells is shown in Figure (8)

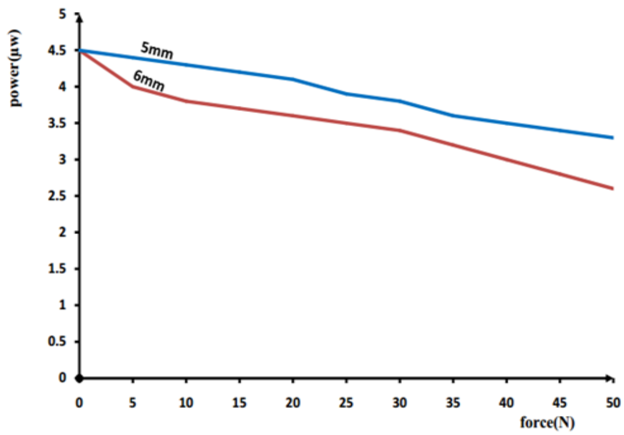

Figure 8. The output power for two microbend cells

The power loss (in percent) of the light transmitted power through the fiber optic as a result of bending deflection was determined from the following equation (4-1)

$$Pl = \frac{100(Ps-Pd)}{Ps} \quad (6)$$

Where

P_l is the power loss, P_s is the power measured for straight fiber optic, and P_d is the power measured for deflected fiber optic of the same length. The calculated output power loss of two model of microbend cells is shown in Figure (9)

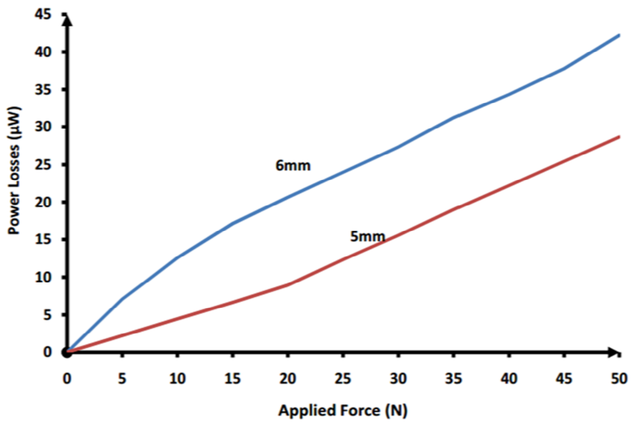

Figure 9. The output power losses for two microbend

From this Fig(9) the power loss of 6mm microbend cell is greater than the power loss of 5mm microbend cell. From this figure we can show the losses of 5mm microbend cell is less than the losses of 6mm microbend cell. Absorbance is dimensionless measurement of the ability of media to absorb light. Absorbance (A) occurs when a photon emitted from a light source excites an electron from a ground state to higher energy orbital, it is represented by the following equation (4-2) [94] .

$$A\lambda = -Log\left(\frac{I\lambda}{I\lambda^{\circ}}\right) \quad (7)$$

Where

$A\lambda$ is the absorbance at specific wavelength (λ), Iλ is the intensity of the light at wavelength λ, Iλo is the intensity of the incident light at wavelength λ before it enters the sample. The absorbance is calculated for two microbend cells is shown in table (1). The relation between applied force and calculate absorbance is shown in Fig (10). From this figure the absorbance of 6mm model is greater than model 5mm. The maxim value of absorbance for 6 mm is 0.985 and 0.891 for 5mm.

Table 4.4. The result of absorbance

Mass (kg)	Absorbance		Force (N)
0	5mm	6mm	0
0.5	0.028	0.047	5
1	0.069	0.123	10
1.5	0.135	0.215	15
2	0.212	0.309	20
2.5	0.315	0.414	25
3	0.421	0.527	30
3.5	0.527	0.628	35
4	0.652	0.757	40
4.5	0.758	0.855	45
5	0.891	0.895	50

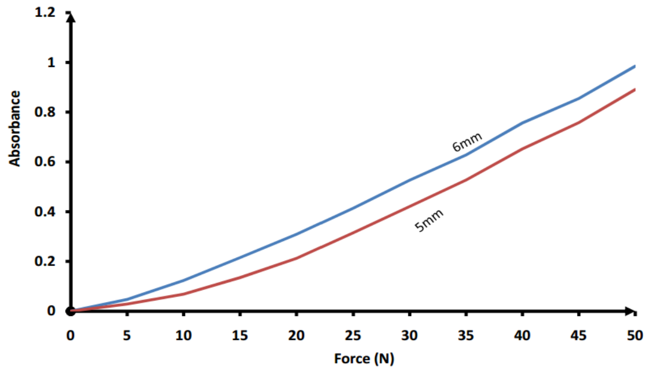

Figure 10. The relation between absorbance and applied force

From all these results are shown by microbending cells the fiber is bent to critical angle and some modes escape from the core to the cladding. It leads to changes in the intensity of back-scattered radiation from the place of effect. The plates in response to a change of physical quantity *ΔE* act by force *ΔF* on the fiber, creating microbendings of the fiber. The change in transmission rate will be appears as a change in optical power detected by the photo detector

Conclusion

In this experiment, we have verified the fact that microbend losses are due to the changing in the applied force. When the force increases that lead to increase in losses and we Observed that the losses in microbend 6mm greater than microbend 5mm. By studying a generic design, the microbend sensor has been examined and optimized.The power results of 6mm cell at different applied force are less than 5mm.The intensity results of 6mm cell at different applied force are less than 5mm.The microbend effect was studied experimentally in multimode fiber at different microbend cells, and it was found that l_s with a value (5and6) mm cause significant losses which can dramatically minimize at (5mm) microbend cell than (6mm).The absorbance results of 5mm cell at different applied force are less than 6mm.

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