SHORT COMMUNICATION

UTILIZATION OF MICROBENDING EFFECTS IN OPTICAL FIBER TO ACT AS A PRESSURE SENSOR

By

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ABSTRACT

This study shows the mechanical effects on the transmitting of diode laser through an optical fiber. Seven threaded aluminum blocks with different dimensions and spatial periods were used to cause microbending. These blocks cross the fiber and are pressed by a pressure unit. Then ensues a relationship between the attenuation of the signal output and the effective pressure. So the conclusion is that the mechanism of microbending can be used in optical fiber to produce a pressure sensor and this is done by measuring the attenuation of the signal output and then finding the value of the effective pressure on the optical fiber, which causes this attenuation.

الملخص:

تظهر هذه الدراسة التأثيرات الآلية على أشعة ليزر الثنائي المارة خلال الليف البصري. استخدمت سبعة أزواج من ألواح الألونيوم المسننة بمختلف الأبعاد و المسافات الدورية من أجل إحداث انحناءات مجهرية في الليف البصري وذلك عند وضعه بين لوحين من هذه الألواح وتسليط أوزان مختلفة عليه مما يؤدي إلى حدوث توهين في الإشارة المارة بسبب هذه الانحناءات. رسمت العلاقة ما بين التوهين الحاصل كدالة للضغط المؤثر والمسافات الدورية. استنتج أن الانحناءات المجهرية، يمكن الاستفادة منها لإنتاج متحسس للضغط باستخدام الليف البصري.

INTRODUCTION

The microbending is one of the passive processes that are undesired in the optical communication field. That is because it affects–during communication-in attenuating signal, and noises in the optical fibers. But it might be useful if it is appropriately well treated [1].

Bending the fiber also causes attenuation. Bending loss is classified according to the bend radius of curvature to: microbend loss or macrobend loss[2].

Microbends are small microscopic bends of the fiber axis that occur mainly when a fiber is cabled. Macrobends are bends having a large radius of curvature relative to the fiber diameter. Microbend and macrobend are very important loss mechanisms. Fiber loss caused by microbending can still occur even if the fiber is cabled correctly. During installation, if fibers are bent too sharply, macrobend losses will occur[1].

Fiber sensitivity to bending losses can be reduced. If the refractive index of the core is increased, then fiber sensitivity decreases. Sensitivity also decreases as the diameter of the overall fiber increases. However, increases in the fiber core diameter increase fiber sensitivity. Fibers with larger core size propagate more modes. These additional modes tend to be more lousy[3].

Optical fiber sensors represent a new branch of optical fiber engineering that has been developed rapidly in recent years. An optical fiber sensor is a length of fiber that modulates the light passing through it when exposed to the changing environment one wish to sense. Besides the optical fiber, the sensor has a light source such as a light emitting diode (LED) or a laser at one end and photodetector at other end at the fiber to register the changes [4].

The optical fiber sensors are divided into two types: The pure optical fiber sensors, where the fiber itself is the sensing element, and the remote sensing in which the fibers are used only to bring light to and from a separate sensing device[1].

In pure fiber sensors the measured quantity interacts directly with the light traveling in the fiber. The resultant light can be intensity, phase or polarization–modulated within the fiber. There, generally, are no optical interfaces at the modulator site. The feed and return fiber may also impose modulation of the light passing within them however giving misleading information or an error. Selecting a proper fiber and arranging for a suitable interaction region become important consideration in the design[3].

A remote sensor involves the use of a special sensing element that is sensitive to the environment one wishes to probe. Subjected to the environment change, such as temperature and pressure, the sensing elements modulate the light leading to and from the sensor by the fiber[3].

The detection process that follows can be calibrated in accordance with the respective changes. The sensing element is also called a transducer, as usually a change of energy form is evolved[4].

Intensity modulation is the most commonly used method and it is easy to implement. Polarization modulation is unique as the state of polarization of the light through the fiber is affected by the environment other methods of modulation are also possible[5].

The sensors are classified according to their applications, such as temperature sensor, pressure sensor, liquid level sensor, displacement sensor and so on[3,6].

One method of detecting and measuring an external pressure is to measure the transmitted light intensity in sections of fiber between two corrugated plates as shown in (Fig. 1). The plates are adjusted initially to exert little or no pressure on the fiber when there is no pressure. External pressures push the plates together, creating tiny bending in the fiber [7-8].

These microbends distort the fiber, allowing modes to be lost. The light intensity at the fiber output decreases as the external pressure is increased[2].

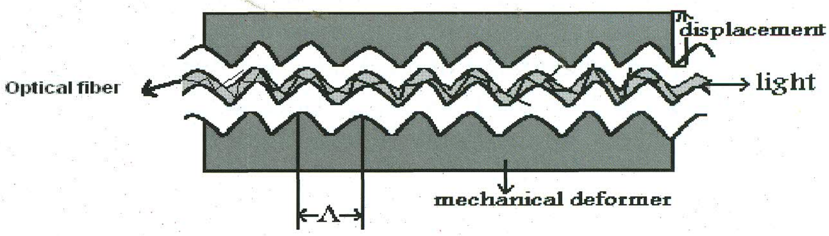


Fig. (1): Microbending in optical fiber due to pressure effect.

The Experimental Work:

The components of the setup were chosen and aligned in order to study the attenuation of the output intensity as a function of the effective pressure affecting the transmission of the laser signal inside the fiber due to the induced microbending. (Fig. 2) shows the arrangement of the used setup[9].

The experimental procedure was done as follows:

1- First of all the laser output intensity, after its propagation through the fiber was measured without any load.

2- The aluminum blocks with dimensions (1x1)cm were inserted in the path of the fiber to work as formatter to cause fiber microbending (1mm) and a mechanical pressure applied on the fiber by using the hydraulic unit with loads ranged between (1–5KN) on the blocks. The attenuation of the laser output was detected for each load magnitude.

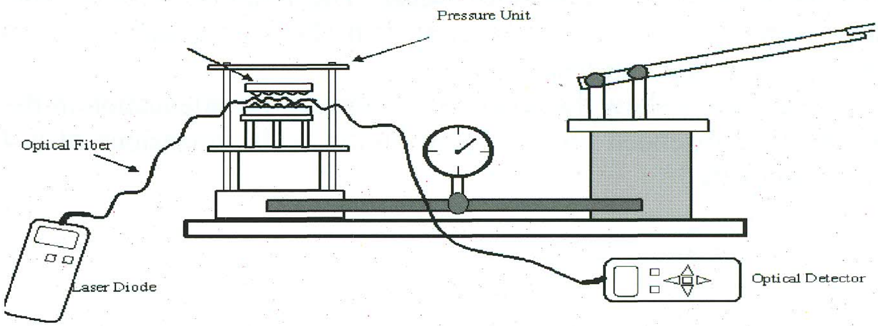


Fig. (2): Experimental setup

3- The aluminum blocks with dimensions (3x3)cm were inserted on the fiber to work as formatter to cause fiber microbending with a different size, (2mm), and the creation force was applied by using the hydraulic unit with loads ranged between (0.1–0.6KN). The attenuation in the laser output was recorded for each case.

4- The aluminum block with dimension (9x4)cm was inserted on the fiber to work as formatter to cause fiber microbending with a different size, (3mm), and the creation force was applied by using the hydraulic unit with loads ranged between (0.1–0.6KN). In each cases the attenuation in the laser output recorded.

5- The effective pressure on the fiber was calculated using the relation:

$$\text{Effective pressure} = \frac{F}{AN} \qquad \ldots\ldots\ldots\ldots \quad (1)$$

Where: F ≡ force applied from hydraulic, A ≡ block area, N ≡ number of threads in aluminum block

6- The attenuation in the laser signal was plotted as a function of the load and the effective pressure in order to evaluate the mechanical effect on the transmitted signal, and to evaluate the possibility of using the fiber as pressure sensor.

RESULTS AND DISCUSSION

This article presents the results of the mechanical effects on optical fiber link, and attempts to follow the analysis of the attenuation as a function of the mechanical load and the effective pressure.

Effect of the Load on the Transmitted Signal: The relations between the laser attenuation and the used loads are plotted in (Fig.s 3, 4, and 5) for microb-endings 1mm, 2mm and 3mm respectively.

These figures show the relationship between the attenuation in the laser output and load extended on aluminum blocks with dimensions of 9×4, 3×3, 1×1cm, respectively.

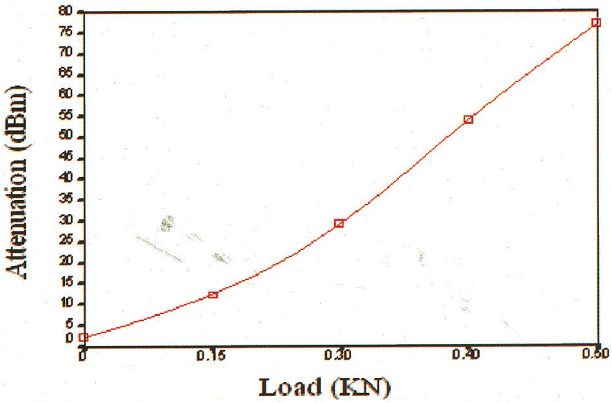


Fig. (3): Attenuation against the load for bending 1mm

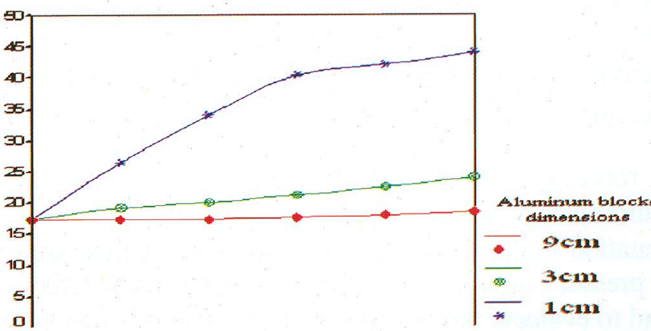


Fig. (4): Attenuation against the load for bending 2mm

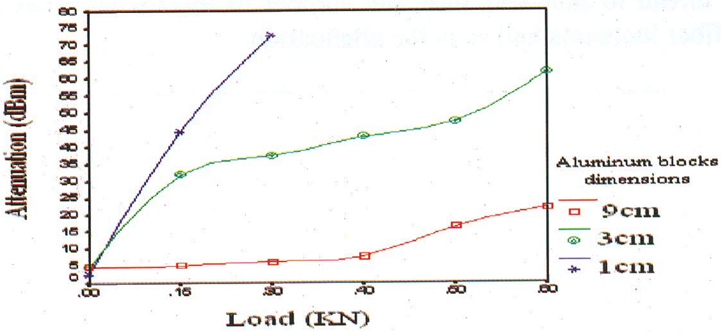


Fig. (5): Attenuation against the load for bending 3mm

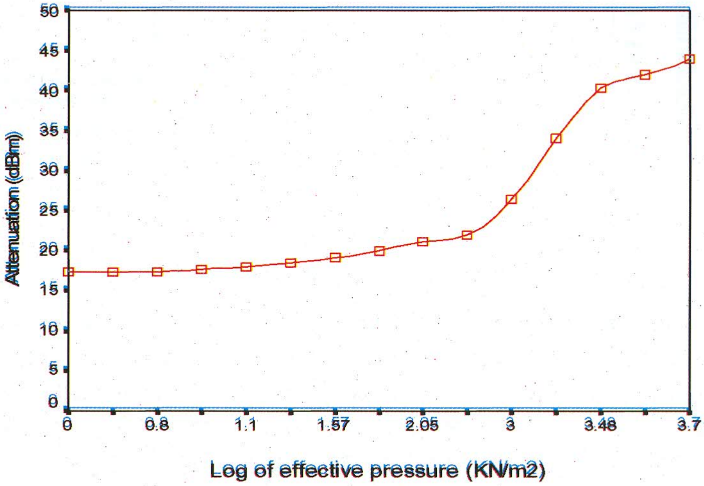
It is clear that the attenuation of the laser output signal increases with the increase in load and this behaviors shows an exponential increasing in the attenuation, and it becomes less with the increase of the length of the aluminum blocks which means that increasing the block length lead to decreasing the effective pressure and hence decreasing the attenuation. The results were similar to these reported by (KHELEEL, *et al.*, 2000)[9].

Effect of the Effective Pressure on the Laser Output: The values of the attenuation correspond to each value of the effective pressure are shown in (Fig.s 6, 7 and 8) for microbending 1mm, 2mm and 3mm, respectively. The effective pressure was calculated using equation (1).

Effect of the Spatial Period on the Laser Output: The relation between the attenuation of the laser output and the diameter of spatial period using a constant external load and blocks length is plotted in (Fig. 9). When the diameter of spatial period is 1mm the resulting attenuation is slight. The increasing of the length of spatial period to 2mm and 3mm with fixed length of aluminum blocks and the load, shows an increase in the attenuation resulting from the spread of the load on all the threads. Actually this leads to increase the effective pressure. The results of the present work were similar to that previously reported by (Ramesh B. Malla, *et al.*, 2003)[2].

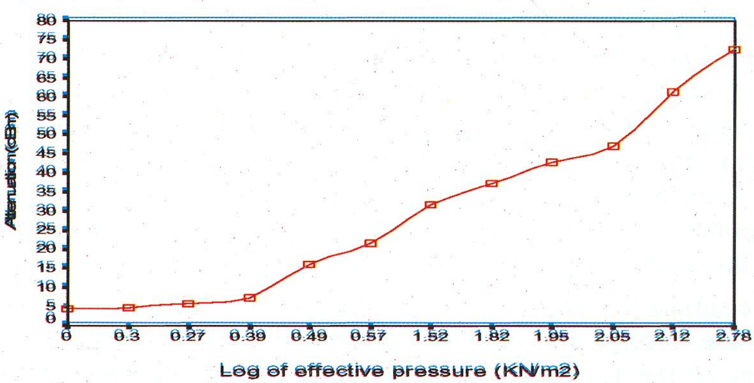
These results are in good agreement with the logical fact that the attenuation of the laser output in optical fiber is a function of the length of aluminum blocks and the effective pressure.

When the diameter of the thread is 1mm, the threads number becomes greater so the effective pressure on the fiber becomes less. With increasing the diameter of thread to 2mm and 3mm, the number of threads becomes less and the load on the fiber increases and so is the attenuation.



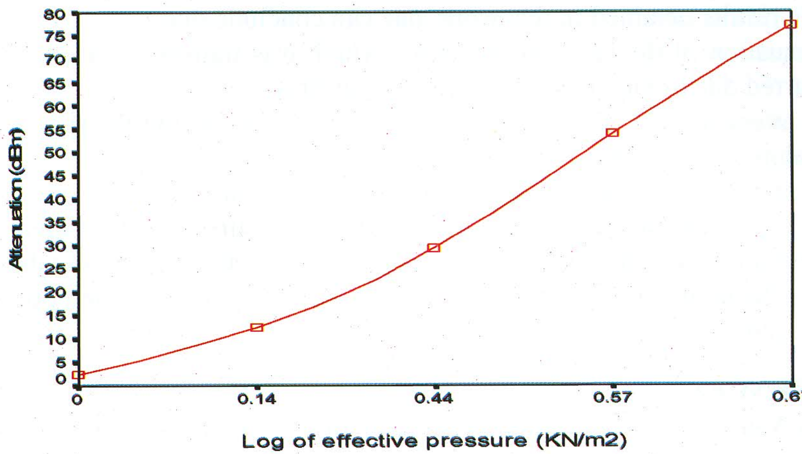
$$\text{Attenuation} = 13.84\, e^{0.27 \cdot eff.\ pressure}$$

Fig. (6): Attenuation in the laser output as a function of the log of effective pressure for (1mm) microbending



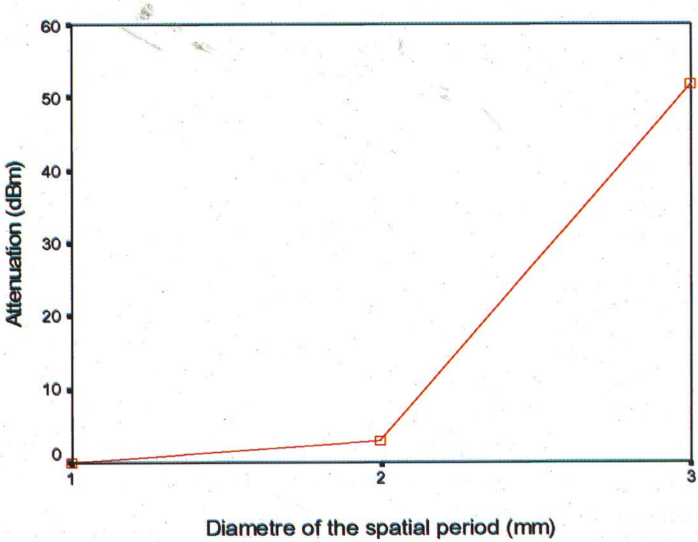
$$\text{Attenuation} = 6.15\, e^{eff.\ pressure}$$

Fig. (7): Attenuation of the laser output as a function of the log of effective pressure for (2mm) microbending



$$\text{Attenuation} = 3.65\, e^{4.73 \cdot eff\ .pressure}$$

Fig. (8): Attenuation of the laser output as a function of the log of effective pressure for (3mm) microbending



External Load = 0.4 KN,Block Dimensions =9x4 cm

Fig. (9): Attenuation of the laser output as a function of the spatial period

CONCLUSION

From the results obtained in this work, one can conclude that:

- Attenuation of the laser output signal which was transmitted through the fiber occurred due to the induced bending in the fiber.
- The attenuation is increased exponentially with increasing the spatial period of the aluminum blocks.
- The attenuation is increased with the load increment.
- For a constant spatial period, the effective pressure was decreased when the aluminum blocks dimensions increased, hence the attenuation was decreased.
- The effects mentioned above prove the possibility of using the optical fiber as a pressure sensor.

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