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Design and Construction of a Laser Pressure Fiber Sensor

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Abstract

This paper investigates optical fiber pressure sensor which based on periodic microbending losses phenomenon. Deform cells made of aluminum material of dimension (30×100) mm are designed and constructed with periodic microbends of spatial periodicity of 8 mm. Distance separation between two deform plates is 6mm and 8 mm through which the optical fiber PCS380 passes. The light emitting diode of 650nm is used as a source. Pressure force has been applied on the deform cells by using various masses (0.5-5) Kg. The mechanical instrument which used to apply pressure force on deform cells. The value of mass appears on an analogous gauge. The output power and intensity spectrum are recorded at different pressure forces.

Keywords : Fiber, Laser, Sensor

بناء وتصميم متحسسات الضغط للألياف الضوئية

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الخلاصة

ان هذا البحث يدرس متحسسات الضغط للالياف البصرية وذلك من خلال ظاهرة الانحناءات المايكروية. ان خلية الانحناء مصنوعة من مادة الالمنيوم ذات أبعاد (30x100) ملم وان البعد الدوري للانحناء هو 8 ملم والذي يمثل المسافة بين كل انحناء وآخر. تم استعمال خلية 8 ملم وخلية 6 ملم مع ليف بصري من نوع pcs380. ان الضوء المار هو ضوء الدايود الباعث للضوء وبطول موجي 650 نانومتر كمصدر ضوئي وسلطت قوة على الخلية باستعمال كتل مختلفة (0.5-5) كغم. وتم ملاحظة التغيير في القدرة والشدة الخارجتين مع مديات مختلفة من قوى الضغط.

الكلمات المفتاحية : الألياف، الليزر، متحسسات

Introduction

Optical fiber sensors are used to measure temperature, pressure, chemical species, strain, moisture, force, displacement, acceleration, etc. [1-5]. Optical fiber, microbend sensor, is based on the control and analysis of couplings and leakage of modes propagating in a deformed microbend optical fiber [6-10]. Sensing of losses in deformed fiber is done by output power measurements.

Optical fiber pressure sensors are widely applied due to their advantages of low cost, light weight, flexible structure design and not being affected by electromagnetic field.

According to sensing principle, optical fiber pressure sensors can be divided into intensity-based, interferometry, polarization, grating sensors and so on [1-2]. Among them, intensity-based sensors enjoy the most simply structure and thus are widely studied in past and present. However, its application is with limitation due to its low sensitivity and poor performance towards the source light power fluctuations.

In this paper, it is concentrated on investigating the use of optical fiber as a microbending pressure sensor. There are two traditional approaches to optical fiber pressure sensors are stress induced attenuation [4] and microbend attenuation [6;7].

Microbending Sensor

Microbending optical fiber sensors based on bend-induced loss in optical fiber have proved themselves useful for detecting environmental changes. Many different mechanical elements have been developed to perform the sensing, each with attributes suitable for a particular application.

The sensor structure can be simple and regular periodical optical microlending is generated to create microbendings in small portion of the optical fiber which is placed between a pair of deformation plates as shown in Fig. (1).

By microbendings 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 of change is of physical quantity *ΔE* acts as a force *ΔF* on the fiber, creating microbendings in the fiber. The change of transfer coefficient *ΔT* according to the applied pressure force can be described by the following relationship:

$$\Delta T = \left(\frac{\Delta T}{\Delta X}\right) \Delta F \left(k_f + \frac{A_s Y_s}{l_s}\right)^{-1} \tag{1}$$

where kf is the force constant of the bent fiber, which can also be thought of as the effective spring constant of the optical fiber, *ASYS/lS* is a force constant with included distance change of plates. *As* the cross-sectional area of the fiber, *Ys* is Youngs modulus, *ls* is the distance length of deformation plates, and ΔT/ΔX relates the change in transmission to the change in fiber amplitude due to deformation, which depends on the modal structure of the fiber. The force constant is traditionally defined as ΔT/ΔX which a coefficient is expressing the rate of change in transmission distortions to change of amplitude deformation ΔX. The change in transmission rate will be reflected as a change in optical power detected by the photo detector. This change of output is therefore used to detect changes in physical quantity ΔE. The attenuation in the place of measurement depends on the pressure force acting on the sensor. The length of the modulator; the distance length of deformation plates and the mechanical frequency (number of teeth) affect the output power measurements.

Experimental work

A series of permanent microbends is introduced onto a 1m step-index plastic fiber of core diameter 380μm and numerical aperture 0.3; by sandwiching the fiber with a pair of corrugated plates at 10 cm deform cell length and applying moderately high pressures of a few kilograms per square centimeter. The distance length of deformation plates used to bend the fiber are 6mm and 8 mm each having a pitch of the corrugation as 8 mm. A schematic diagram and a photographic picture of the experimental setup is shown in Fig (2).

Deformation plates, made of grooves, allow using the sensor in two models at different *lS* (6 mm and 8 mm). Input and output part of the optical fiber is fixed in foam pieces to prevent damage. Mutual positions of plates are fixed. Minimum used load pressure force was chosen with respect to the accuracy of sensing, maximum load pressure was chosen to prevent damage of the fiber.

Laser (He-Ne) wavelength 650 nm is launched at one end of the optical fiber. The output power was measured with a power meter (Lambda LLM-2 Light power source) or recorded as intensity spectrum by using spectrometer (Ocean Optics HR 2000) and the results are displayed on personal computer. The pressure is achieved with the help of a mechanical instrument. The pressure force on the sample increased in steps from (5-50) N and corresponding outputs are recorded. The experiment has been performed under laboratory conditions. Hence, the modulation in output power is only due to change in pressure on the sample.

Result and discussion

In an optical fiber the effect of pressure is mainly confined to the plastic jacket and the cladding. There is little deformation of the core. Hence, if pressure force is increased, the nature of the fundamental and other lower order modes changes very slightly.

Power transmitted in the optical fiber is shared by the core and cladding. With pressure increasing, the coupling takes place between the cladding modes and higher order core modes. However, the lower order modes are tightly concentrated in the core region with little penetration into the cladding region. This wavelength is transmitted through MMF, where this fiber is passed through microbend cell at 6mm or 8mm.

Fig (3) shows the increase of applied force at range from 5N to 50N and the decreased output power. The reference power means no applied force on two microbend cells is 18µw. The output power from (6mm) microband cell change from 18µw to 16.8µw at the force range from 5N to 50 N and the output power from the second microbend cell (8mm) are varies from 60µw to 20.1µw at the same range of applied pressure force .From this figure the output power at 8mm microbend cell is less than 6mm microbend cell because the 8mm model is greater bend than the 6mm model ,that means increased the bend losses. Curves 'blue' and 'red' show that as pressure force increases, normalized output power decreases.

The power loss (in percent) of the laser transmitted through the fiber optic as a result of bending deflection was determined from the following equation [7]:

$$P_l = \frac{100\,(P_s - P_d)}{P_s}$$

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 optical fiber of the same length.

The output power loss of two microbend cells is shown in fig (4).

From this fig (4) the power loss of 8mm microbend cell is greater than the power loss of 6mm microbend cell.

Intensity spectrum of the laser for different applied force is shown in figure (5). The intensity spectrum is decreased when the applied force is increased for two microbend cell models. The intensity at the range of applied force is shown in figure (6). Output intensity is decreased with increased force for both models.

Absorbance is dimensionless measurement of 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 [11]:

$$A_\lambda = -\log(I_\lambda / I_{\lambda o})$$

where

A_λ is the absorbance at specific wavelength (λ)

I_λ is the intensity of light at wavelength λ

$I_{\lambda o}$ **is** the intensity of incident light at wavelength λ before the incidence on the sample.

The calculated absorbance of two models is shown in fig (7). The absorbance of 6mm is less than 8mm because the second model is being bent greater than the first model and the losses in 8mm is higher.

From all these results the fiber is bent to critical angle and some modes escaped from the core to the cladding. It leads to changes in the intensity of back-scattered radiation in the place of effect. The plates in response for the change of physical quantity *ΔE* act by force *ΔF* on the fiber, creating microbendings in the fiber. The change of transfer coefficient Δ*T* according to the applied force can be described by the relationship in equation (1)

The change in transmission rate will appear as a change in output optical power detected by the power meter detector.

Conclusions

Microbend sensors have many advantages and applications in different fields. microbending effect is considered in multimode fibers as a transduction mechanism for sensing environmental change. An optimized generic microbend sensor was built and utilized to detect applied pressure force.

By studying generic design, the microbend sensor is examined for pressure measurements. dynamic range of the sensor for the length of plates 100 mm and width 30mm is from 5 to 50N. The sensor was examined in laboratory conditions.

The loss increases strongly depend on the pressure force, using different pressure force, the less losses possible when the pressure force is (5) N.

The power and intensity results of 8mm cell at different applied force are less than 6mm.

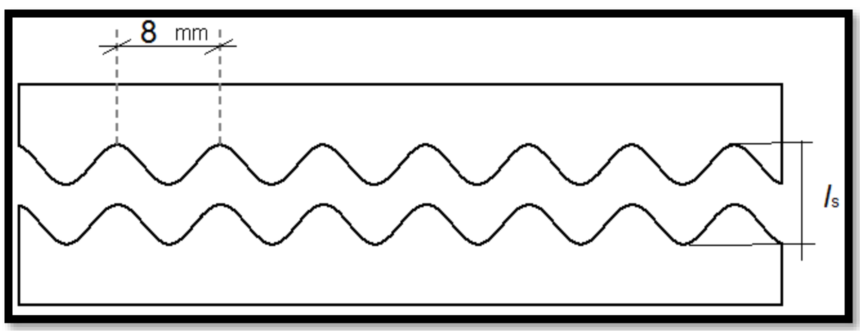

Fig (1) Geometry of microbending cell [4].

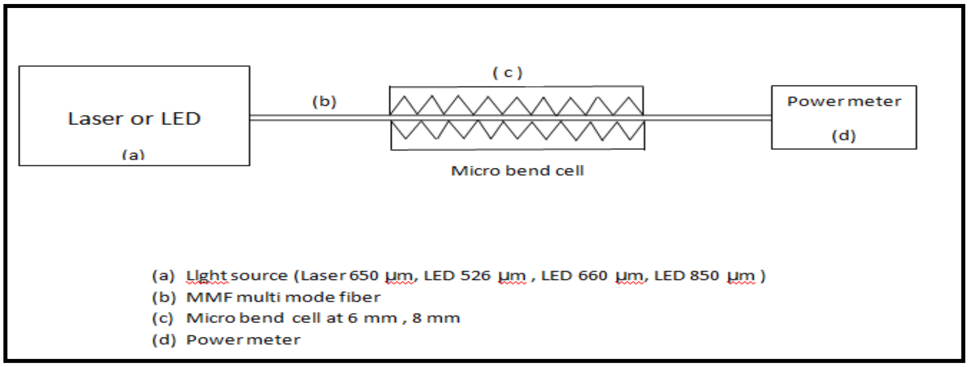

Fig (2) (a) schematic diagram and (b)photographic picture of experimental setup.

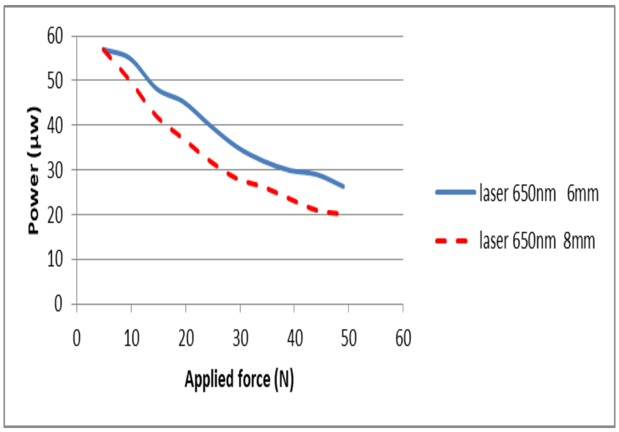

Fig (3) the output power for two microbend cells.

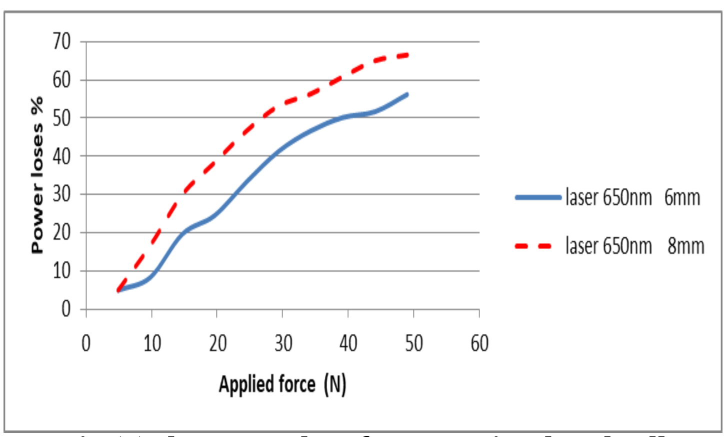

Fig (4) the power loss for two microbend cells.

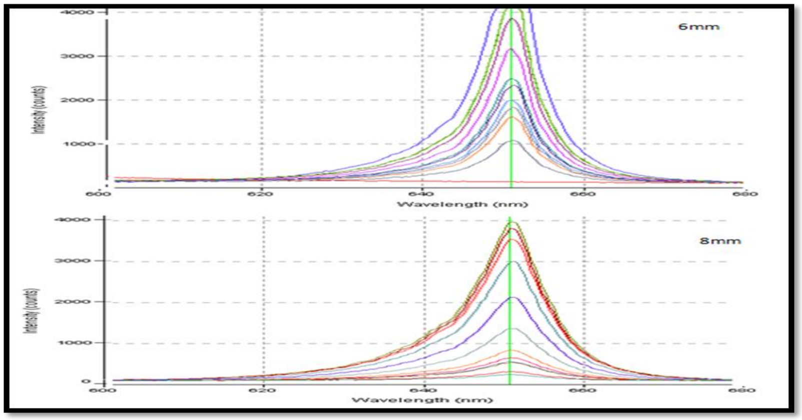

Fig (5) the intensity spectrum of two microbend cell 6mm &8mm.

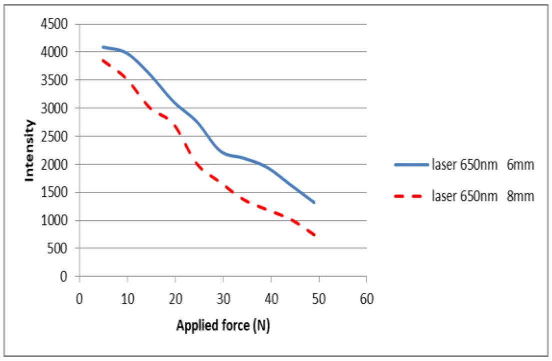

Fig (6) output intensity as a function of applied force.

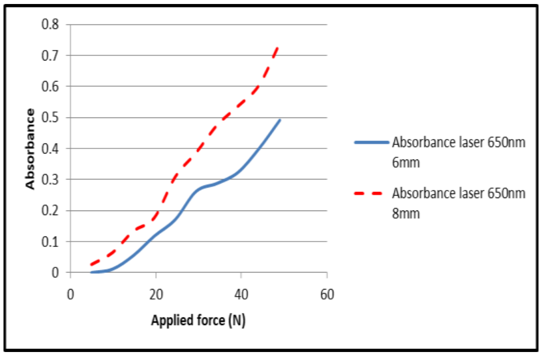

Fig (7) calculate absorbance for two models of laser.

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