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DEVELOPMENT OF OPTICAL BIOSENSOR BASED ON MICROBENDING TECHNIQUE

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Abstract In orthopedic treatments, measuring the strain makes it possible to monitor the bone fracture healing process. With the recent development of biosensors, it is now possible to monitor the strain on the bones. For this purpose a number of biosensors have been proposed. However, not much work has been done in the field of photometric sensors. Micro bend sensors are based on micro bend induced excess transmission loss of an optical fiber to detect/measure displacement, pressure, strain, temperature etc. A Fiber Optic Biosensor is modeled

Keywords- Attenuation, bones, fiber optic biosensor, linear, micro bend, strain.

I INTRODUCTION

Bones have a natural and physiological ability to regenerate themselves. After a fracture, bone cells temporary proliferate at the fracture site to form a reparative tissue. During the healing process, the fractured bone is subjected to various treatments. Bone loss, new bone breakage and improper healing are complications that sometimes arise. In order to anticipate such failures, proper monitoring is required [1]. With the recent development of biosensors it is now possible to monitor the strain of the bones. For this purpose a number of biosensors have been proposed. These are mechanically robust micro fabricated strain gauges for use on bones, micro scale sensors for bone surface strain measurement and polyimide based single walled carbon nanonets flexible strain sensor for bone [2],[3],[4],[5]. Most of the researches have focused on using electrical transducers for measurement of strain but not much work has been done in the field of photometric sensors. The photometric sensors have the advantage of being chemically inert. They do not cause thrombosis. Moreover these are light flexible and EMI/RFI immune. Also such biosensors are electrically inert reducing the fear of patients in terms of shocks etc. With the improvement in biosensor for measuring the strain on bones it will be possible to more accurately detect the onset of osteoporosis.

Micro bend sensors are based on micro bend induced excess transmission loss of an optical fiber to detect/measure displacement, pressure, strain, temperature etc. If a portion of fiber is deformed, the fiber would exhibit excess light loss [6],[7],[8] . Such perturbation of fiber axis results in redistribution of guided power between modes of the fiber and also coupling of the fiber from one mode/mode group to another. Also, Artificial Neural Networks are viewed here as parallel computational models, with varying degrees of complexity, comprised of densely interconnected adaptive processing units.

II METHODS AND MATERIALS

Intensity modulation induced by microbending loss in multimode fibers can be utilized as a transduction mechanism for detecting environmental changes. In ray description due to sharp bends in the fiber, there will be some light rays falling at the core cladding interface at an angle less than the critical angle, thus preventing their total internal reflection. These rays will thus be lost from the guiding structure. As the fiber is bent more and more sharply, so more and more number of rays will thus be lost and at a certain bend radius defined by the fiber geometrical characteristics, the bend loss becomes very steeply dependant on bend radius and the micro bend sensor takes advantage of this very fact. Such sensors can be made very sensitive being capable of measuring displacement down to 10-3 microns and strains to 10-7 and pressure up to 10-6 kg/mm2.

If λs the spatial wavelength of periodic deformation, satisfies the following phase matching condition between pair of modes,

$$\beta_p - \beta_q = \frac{2\pi}{\lambda_s} \qquad (1)$$

where βp and βq represent modal propagation constants, then power transfer will occur from pth path to qth mode. If qth mode happens to be a radiation mode, then this transfer of power will result in a net transmission loss of the guided modes. From theory of coupled modes, it can be shown that for the case of step index fiber of core radius 'a', core index n. The relative core cladding difference, required to induce heavy transfer of power from highest order guided modes to radiation modes will be given by the expression

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$$\lambda_{cr} = \frac{\pi\alpha}{\sqrt{\Delta}} = \left(\frac{\sqrt{\pi}.a.n_1}{N.A.}\right) \qquad (2)$$

Where α = Profile index of fiber,

△ = Relative indices difference,

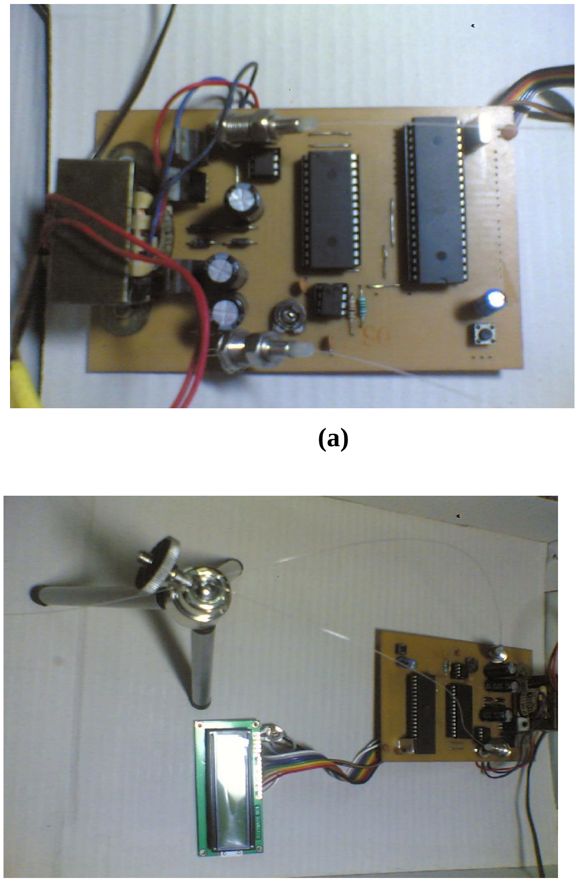
a = Radius of fiber core,

n1 = Refractive index of fiber core,

N.A. = Numerical Aperture.

III RESULTS AND DISCUSSION

A data acquisition system has been modeled in UIET Lab of PU Chandigarh. It comprises of various major units viz. Fiber Optical Receiver, biosensor, and Analog to digital converter. It is shown in Fig. 1.



(a)

(b)

Fig. 1. Data acquisition system for biosensor (different views)

In the measuring unit the Fiber Optic Receiver converts the light intensity from the optical fiber coming from the biosensor fixed at the SMA connector into an electrical signal. This signal is then amplified. The amplified signal is then given to filter circuit. The filter conditions the signal to be input to the Analog to Digital Converter (ADC). The ADC converts the Analog signal into Digital signal. Digital signal is given to the microcontroller for analysis.

The software has been implemented in native MCS51 assembly language. It is kept compact and modular. Separate routines have implemented to initialize the system, handshake with the ADC for multiplexing. The results are acquired and displayed. Due to micro bend compensation, suitable corrections from a lookup table are applied to the results. A strain gage conventional sensor has also been attached along with this fiber optic biosensor for calibration and checking the accuracy of this sensor.

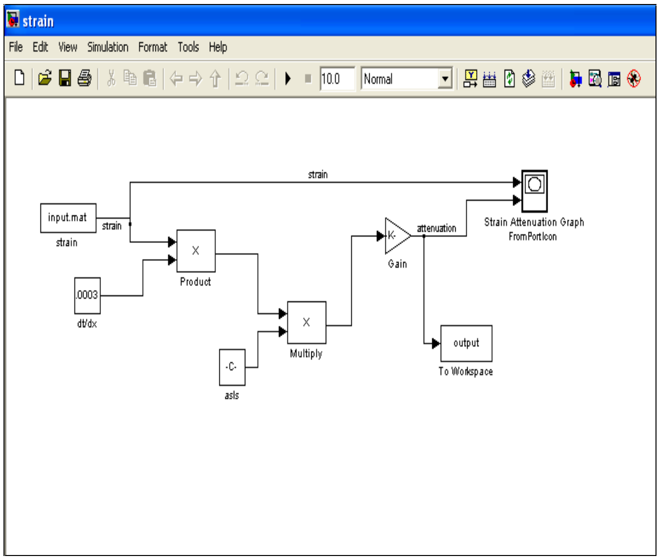


Fig. 2. Simulink model of Fiber Optic biosensor ,

The verification of the data collected was performed by theoretical modeling. The model was constructed in simulink for this purpose. It is shown in Fig. 2. In the present simulink model with the change in the strength of strain the respective attenuation is being measured.

IV CONCLUSION

In the present research, it is proposed that with the improvement in biosensor for measuring the strain on bones it will be possible to detect more accurately various failures during the fracture healing process. For such an improvement a model of fiber optic biosensor is developed. The accuracy of the said sensor is checked with the aid of conventional strain gauge sensor. On the basis of the system developed a simulink model is designed. The present simulink model will be further tuned to get the strain vs. attenuation linear response by optimizing various parameters from the collected data.

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