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Interrogator for FBG Strain Sensor

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Abstract:-- **A structural health monitoring system (SHM) is the need of the hour because continuous monitoring of large structures is a cumbersome task. In this paper a fiber Bragg grating (FBG) sensing system for strain measurements is being described. Economically feasible and simple grating based FBG has been used to produce strain and induced voltage corresponding to wave length shift. The fiber optic grating sensors have been used in this research work in static operating conditions. The feasibility of using a FBG sensor system in real time monitoring of strain in an optic fiber has been demonstrated experimentally. Experimental and theoretical results showing capability of the proposed system to perform strain measurement and giving an approximate linear response are presented.**

Index Terms:-- **fiber Bragg grating, optical fiber, strain sensor, wave-length shift**

I. INTRODUCTION

Civil infrastructures such as long span bridges, offshore structures, large dams and other hydraulic engineering, nuclear power stations, tall buildings, large space structures and geo technical engineering etc. often have a long service period , maybe several decades or over one hundred years, during which they are inevitable to suffer from environmental corrosion, long term loading or fatigue effects, material aging or their coupling effects with extreme loading, and then the damage accumulates, performance degenerates or capacity resisting from disaster actions reduces and even disaster occurs since their failure under the extreme loading. Therefore an intelligent Structural Health Monitoring system (SHM) becomes more and more important technology to study the damage or even to predict disaster. This SHM with FBG strain sensors will be very useful to reduce the maintenance costs with increased levels of safety.

II. FIBER SENSOR MODULE

In a typical optical fiber sensor, light from a source such as a laser diode or LED is guided by an optical fiber to the sensing region as shown in the fig.1 Some property of the propagating light beam such as intensity, phase, state of polarization or wavelength gets modulated due to change in pressure, temperature, strain, magnetic field and so forth. The modulated light is then sent via another (or the same) optical fiber for detection and processing. Optical-to-electrical conversion is obtained using photo detectors and thus enables any measurements to be performed through the information of optics.

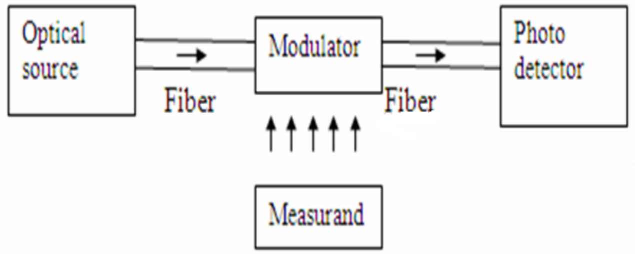

Fig.1 Block Diagram of Fiber Sensor

III. DIFFERENT FIBER OPTICAL SENSING TECHNIQUES

Techniques of implementation of optical fiber sensors are very wide and broad. Some of the major sensing techniques of optical fiber sensors based on modulation are discussed here.

a. *Intensity Modulation Sensors*

The basic concept of intensity based sensors is very simple, in this intensity of either reflected or transmitted light is modulated by the measurand. The major limitation of any intensity based sensor is the lack of any suitable reference intensity signal. Any intensity fluctuations in the output which may not be associated with the measurand may produce erroneous results [2].

b. *Phase Modulation Sensors*

The total phase of light path along an optical fiber depends on three properties of the fiber guide namely-

i. Total physical length.
ii. The refractive index and index profile.

iii. The geometrical transverse dimension of the guide.

In this type of sensors transmitted and reflected light are compared using various techniques to detect any change in phase caused by the measurand.

c. *Wavelength or Frequency Modulation Sensors*

In this type of the sensor the wavelength of the transmitted and reflected light in the fiber is modulated by the measurand. The commonly used sensor is Fiber grating sensor which is discussed as follows:

Fiber grating sensor:

Bragg gratings are periodic refractive index variations written into the core of an optical fiber by exposure to an intense UV interference pattern. For a Fiber Bragg grating (FBG) sensor [7], changes are enclosed as changes in the periodicity or refractive index of the grating thereby causing shift in the wavelength of the reflected wave or transmitted wave. The measurements of the measurand are achieved by detecting the wavelength of the reflected wave or transmitted wave.

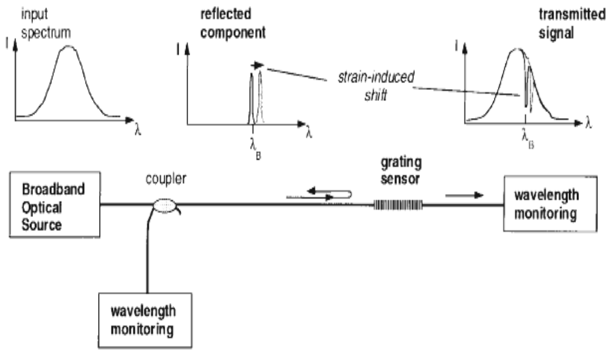

Fig.2 Basic grating-based sensor system with transmissive or reflective detection options

When broad band light propagates through the FBG the wavelength of light satisfying the Bragg condition is given as

$$\lambda_B = 2\, n_{eff}\, \Lambda$$

where, λ_B is the reflected Bragg wavelength,

n_{eff} is the average refractive index of the fiber core,

Λ is the grating spacing..

A part of light will get reflected and remaining will be transmitted. The spacing of the periodic variation of the refractive index will change because of external stress on the fiber. Also as a result of the strain-optic effect the average refractive index will be changed. Thus a shift in the Bragg wavelength is observed. This shift can be expressed as [1],

$$\frac{\Delta\lambda_B}{\lambda_B} = K\varepsilon$$

where K is a constant, Δ□ B is the wavelength shift and ε is the applied strain.

IV. EXPERIMENTAL TECHNIQUE

We are proposing a method for real time monitoring of the strain. Fig.3 shows the experimental setup of the proposed FBG interrogation system. Light from the Broad Band source (ASC) passes through the 3-port circulator to the FBG that is instrumented. The part of input light satisfying the Bragg condition is reflected and rest is transmitted. A physical elongation has been produced creating a tensile in the FBG.

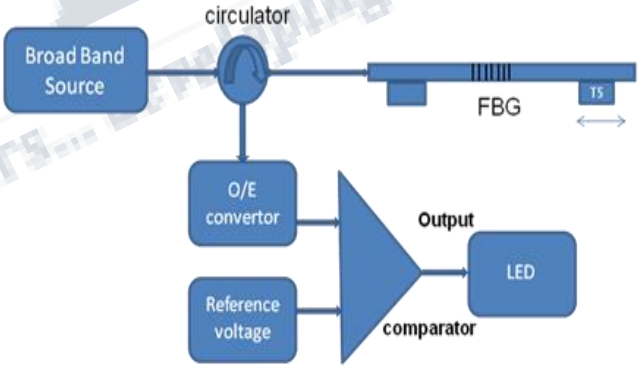

Fig.3 Experimental set-up

As the wavelength □ B is shifted corresponding to the applied strain, therefore, calibration is mandatory to achieve a precise relation between the wavelength shift and the physical signal being measured. For that the shifted wavelength is given to the Optical to Electrical converter (here it is OSA itself) where the wavelength shift is converted into the voltage which is given to the one input of comparator and second input of comparator is Reference voltage. The reference voltage is set on the lowest possible value of the voltage corresponding to the maximum value of the strain that a FBG can bear. If the sample voltage is greater than the reference voltage than the output of comparator will be negative and whenever the sample voltage is less than the reference voltage output will be positive, and indicator in the output of the comparator will glow showing maximum limit of strain is crossed.

A relationship exists between the wave-length shift i.e. caused due to strain and analog output voltage. We are using this relationship in our program. The experimental values of wavelength shift for applied longitudinal stress in terms of elongation are obtained from OSA and corresponding analog output voltage of the OSA is observed on digital storage oscilloscope (DSO) and tabulated in the table.1

Table 1. Output voltage for wavelength shift corresponding to longitudinal stress

Longitudinal Stress(µm) (elongation)	**Wavelength Shift(nm)**	**Voltage (mv)**
00	00	90
10	0.01	87.5
20	0.02	85
30	0.03	82.5
40	0.05	82.5
50	0.09	80
60	0.12	80
70	0.14	77.50
100	0.21	77.50
110	0.23	80
120	0.24	75
130	0.26	75
140	0.27	75
150	0.27	75
160	0.28	72.5
170	0.29	72.5
180	0.31	72.5
190	0.34	70
200	0.35	67.5
210	0.37	67.5
220	0.38	65
230	0.39	65
240	0.39	62.5
250	0.42	60
260	0.43	57.5
270	0.43	57.5
280	0.44	57.5
290	0.45	57.5
300	0.46	55
310	0.47	55
320	0.48	55
330	0.50	50

V. RESULT AND DISCUSSION

The experimental values of the Bragg wavelength shifts were obtained from the reflected signal and corresponding value of voltage is measured on Digital Oscilloscope (DSO). The plot were drawn between the wavelength shift and voltage as shown in the fig.4 The alert system which glows when the applied strain is beyond the maximum limit is successfully demonstrated.

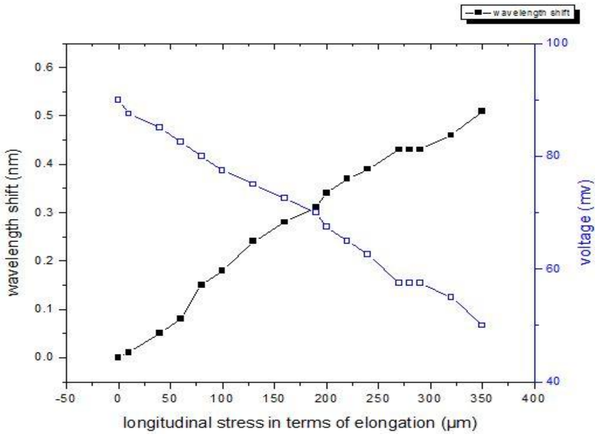

Fig.4 Voltage Vs Wavelength Shift.

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