Fibre Optic Bragg Grating Sensors: A New Technology for Smart Structure Monitoring in Malaysia

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Abstract: Optical fibres are well known for their importance as transporter of information. However, much has been said and proved that optical fibres are essential and play their role as producers of information, that is as sensors. Recent research has proved that fibre optic sensors can be integrated in structure such as multistorey buildings, dams and bridges with the capability to monitor their strength and integrity. One component that is increasingly being used in communication and sensing is Bragg grating. A study in the implementation of a fibre optics Bragg grating (FOBG) sensors system is discussed in this paper. This study concentrates on the issues related to the utilization of FOBG sensors in smart structures.

Keywords
Optical fibres, fibre optic sensors, Bragg grating, strain sensors, smart structures.

I. INTRODUCTION

The importance of monitoring structure for public safety needs to be emphasized in this information age. Such monitoring will gather information on the 'health' status of a structure and thus leads to preventive action rather than merely a rescuing action. With the recent development in fibre-optic sensors (FOS)[1], this proactive action may be realized. The small physical size of such sensors is important in maintaining the strength of the structure when they are embedded. Another requirement in monitoring huge structure is the large number of sensors that are necessary. This requires multiplexing techniques and FOS's are well suited for such application. Beside these, there are a variety of FOS's to choose from, that are easily fabricated.

In Malaysia, optical fibres were used unnoticed by the general public in the 1980's. During the 1990's, the development in telecommunication using optical fibres was dramatic with optical fibre cables being installed along the PLUS highway networks, the National Grid lines and also via undersea cables along the coastlines. Apart from this development in the telecommunication field, research works in using optical fibres for sensing started to emerge. The availability of fibre optics components for communication assists in this recent development. One such component is the fibre optics bragg grating [2].

II. FIBRE SENSOR FOR SMART STRUCTURE

A FOBG may be written into a Ge-doped fibre by exposing it to ultraviolet light. The variation in refractive index so produced, forms an interference pattern which acts as a grating. The grating is wavelength-sensitive and reflects a certain wavelength λ given by equation 1.

$$\lambda = 2\, n\, \Lambda \qquad (1)$$

where Λ is the periodicity of the refractive index variation and n, the effective refractive index of the core. This equation forms the basis of any wavelength-modulated FOBG sensors. Environmental factors such as pressure, temperature and strain, which effectively change the periodicity of the grating, may thus be measured. A simple strain monitoring system utilizing this idea is shown in Fig. 1.

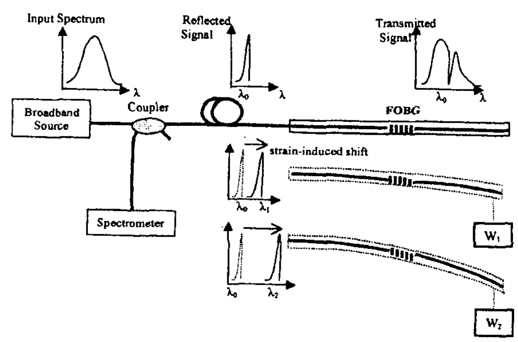

Fig. 1 : A strain monitoring system using fibre optic Bragg gratings

The simple scheme shows the concept of measuring strain in a beam that is translated into a shift in wavelength of light reflected from the FOBG. This type of FOS which is wavelength-modulated, has a unique advantage over any intensity–modulated sensor, since no referencing method needs to be considered for any power losses in the system. Other advantages include its linear response and its multiplexing capability [2]. The latter advantage will be discussed in the following section.

III. BASIC ISSUES IN SMART STRUCTURE

Having chosen the appropriate sensor for the monitoring system, there are other related issues to be considered such as where should they be placed, the number of sensors involved and how are they to be interrogated. These issues are important because they are related to the type of multiplexing techniques that should be used to identify the various sensors present in the whole setup. A number of multiplexing techniques are available but with FOBG sensors, the wavelength-division multiplexing (WDM) and time-division multiplexing (TDM) schemes are normally used [4]. A scheme such as that shown in Fig. 2 may been developed, taking the case of two sensors only.

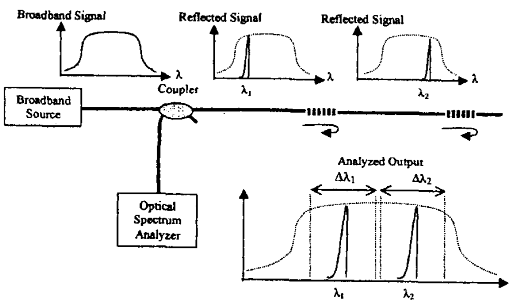

Fig. 2 : A WDM scheme for FOBG sensors

A broådband optical signal is input into the system. Each grating along the sensing line will then reflect light within its wavelength range ($\Delta\lambda_1$ or $\Delta\lambda_2$) specified by the peak wavelengths (λ_1 or λ_2). The returning signal from each sensor may thus be analyzed by an optical spectrum analyzer (OSA). In an actual setup, the OSA may be replaced by a simple filtering scheme. For a typical broadband source with a 100 nm bandwidth and a sensor spacing of 5 nm, an array of 20 sensors is possible. This number may also be increased if a TDM scheme is integrated into the WDM scheme.

Another issue that needs to be addressed in smart structure monitoring is the implementation of an ingress/egress method at the structure interface. This is to ensure that the sensors embedded inside the structure are always linked to the instrumentation outside it, with minimal power losses. For harsh-environment application such as involving concrete [5], special care must be taken to provide extra protection against human as well as material 'corrosiveness' during and after installation.

An important element in a smart structure is the control system. The basic issue here is how can it be implemented for a FOS system and whether an optical neural network processing is necessary. We will leave it here for the moment.

IV. PRACTICAL ISSUES IN MALAYSIA

From what have been outlined above, it is obvious that implementing a fibre optic smart structure requires a multidisciplinary effort. Firstly, there is the material aspect to be considered with regards to embedding optical fibres into different types of structure so that the structural integrity is not compensated. Secondly, fibre optic sensors for different measurands need to be designed and constructed before the engineering problem of embedding or bonding is solved, or be solved together. Then, finally, the schemes for signal multiplexing and processing should be made available to complete the smart structure monitoring. For such a multidisciplinary research work, the final target should be definite and clear to each component member. As far as the fabrication of FOBG is concerned, the facility is available here and it may be acquired locally at a reasonable price. Other fibre optics components are also easily acquired. Finally, what is also necessary is the basic instrumentation which ought to be designed and constructed locally.

V. CONCLUSIONS

The measurement method that is discussed here is a non-destructive testing method which can monitor continuously, if so desire, smart structures and thus giving the complete 'history' of the structure once it is embedded inside it, throughout its lifetime. This is not only an advantage but necessary, where early symptoms of defect within the structure would be made known as early as possible for possible repair, thus ensuring public safety. The system may thus be regarded as an early warning system to avoid a major disaster affecting the general public. The issues raised here foresee the requirement of a collective effort for a beneficial implementation of such a smart structure involving the use of FOBG. It is hope that this paper will gather momentum in research towards this goal.

VI. REFERENCES

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