Smart Building Health Monitoring with Fibre Bragg Grating Technology

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Introduction

- The progress of smart building is always existing, which requires high response, pinpoint accuracy and multifunctional.
- This project investigates fibre Bragg grating (FBG) technology including its working principle and sensing applications.
- This project presents FBG-based sensors for real-time building health monitoring, both contemporary building and historical church.

Objectives

- To learn the fundamental knowledge of fibre optics and optical sensor technology.
- To achieve a comprehensive study of fibre Bragg grating technology.
- To study FBG sensors for building monitoring by measuring strain and temperature.
- To gain my personal soft skills, such as self-study ability, writing skills, communication skills and report skills.

Fibre Bragg grating (FBG)

- FBG is written by UV laser to produce an increase in refractive index of core of fibre with periodic structure.
- FBG couples light from fundamental core mode to the backward-propagating cladding modes [1].
- The Bragg wavelength is given by [1]:

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

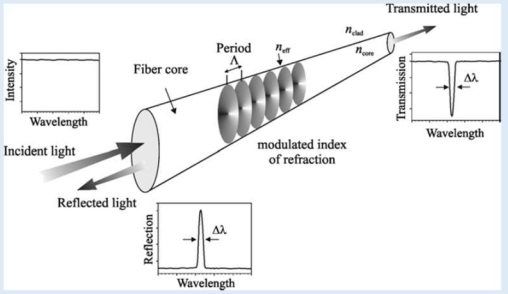

Fig.1. Schematic diagram of FBG.

Sensing Principle of FBG

- **Strain measurement**
  For an applied strain $\Delta\varepsilon$,

$$\Delta\lambda_{BS} = \lambda_B(1-\rho_\alpha)\,\Delta\varepsilon$$

- **Temperature measurement**
  For an applied temperature change ΔT,

$$\Delta\lambda_{BT} = \lambda_B(1+\xi)\Delta T$$

- **Cross-sensing compensation**

$$\begin{pmatrix}\Delta\lambda_{B1}\\ \Delta\lambda_{B2}\end{pmatrix} = \begin{pmatrix}K_{\varepsilon1} & K_{T1}\\ K_{\varepsilon2} & K_{T2}\end{pmatrix}\begin{pmatrix}\Delta\varepsilon\\ \Delta T\end{pmatrix}$$

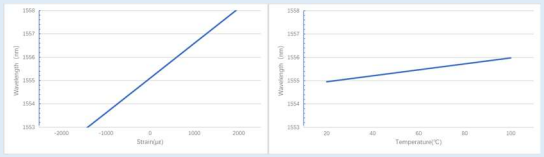

Fig.2. Sensitivities for strain and temperature.

The K-matrix can be determined by separately measuring the wavelength shift against strain and temperature.
If K is known, $\Delta\varepsilon$ and ΔT can be easily determined.

Smart Building Health Monitoring

i) Contemporary TV Tower

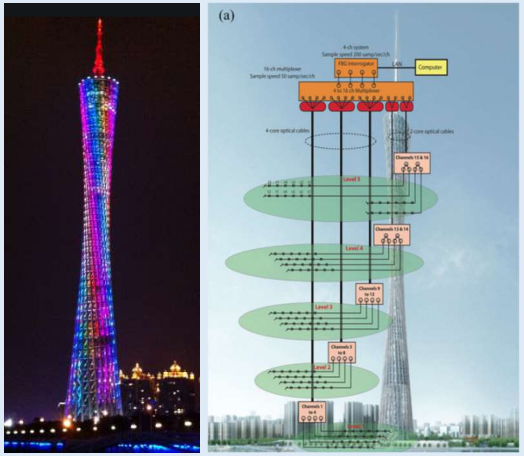

Fig. 3. FBG system for Canton TV Tower.

- Canton Tower (China), 610-metre-tall, 2009
- 200 FBGs (144 for strain, 56 for temperature) [2]
- To provide real-time structure health monitoring: torsion, sway, tilt, vibration …

ii) Historical Catholic Church

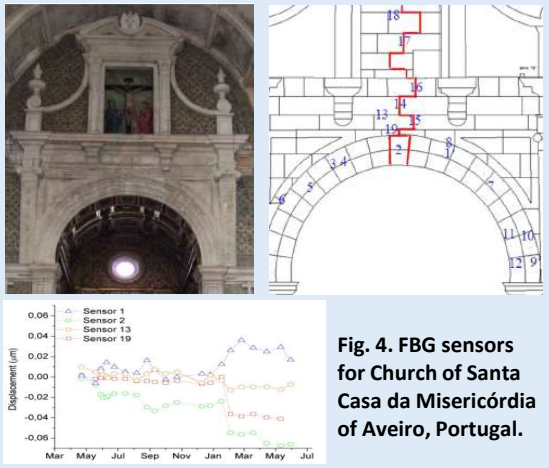

Fig. 4. FBG sensors for Church of Santa Casa da Misericórdia of Aveiro, Portugal.

- To gather data of historical structure behaves & to help planning the recovering interventions [3].
- 24 FBGs used (19 for displacement, 5 for ΔT)
- Successfully monitored structure changes caused by an earthquake (5.9 magnitude, Feb. 2017).

Conclusion

This project explored the strain and temperature sensing characteristics of FBG, and discussed the practical applications of smart building health monitoring system. The temperature and strain sensitivities for a 1550nm FBG are 12.7 *pm/°C* and 1.5 *pm/με*, respectively.

Acknowledge

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Reference

[1]. A. Othonos et.al., Fibre Bragg Gratings. In Wavelength Filters in Fibre Optics, Springer, pp. 189-269, 2006.
[2]. H. Tam et.al., "Distribution Optical Sensor System on the 610-m Guangzhou New TV Tower," Opt. Fibre Comm. Conf. and Expo. LA, USA, pp. 1-3, 2011.
[3]. H. Lima et.al,. "Structural Health Monitoring of the Church of Santa Casa da Misericórdia of Aveiro Using FBG Sensors," IEEE Sensors Journal, Vol. 8, pp. 1236-1242, 2008.