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On a fiber grating sensor system with the capacity of cross-sensitivity discrimination

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Abstract

A novel fiber Bragg grating (FBG) sensor system based on an interrogating technique by two parallel matched gratings was designed and theoretically discussed. With an interrogation grating playing the role of temperature compensation grating simultaneously, the wavelength drifts induced by temperature and strain were discriminated. Additionally, the expressions of temperature and strain were deduced for our solution, and dual-value problem and cross sensitivity were solved synchronously through data processing. The influence of the FBG's parameters on the dynamic range and precision was discussed. Besides, the change of environment temperature cannot influence the dynamic range of the sensor system through temperature tuning. The system proposed in this paper will be of great significance to accelerate the real engineering applications of FBG sensing techniques.
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Keywords: Fiber Bragg grating sensor; Interrogation techniques; Cross sensitivity; Dynamic range; Dual value

1. Introduction

Fiber Bragg grating (FBG) sensors have been widely used in various fields for more than 10 years because of their self-referencing capability and suitability for use in multiplexed sensor networks and smart structures [1–3]. In order to read the wavelength-coded signal easily, rapidly and accurately, and to avoid the cross-sensitivity effect, various methods have been reported and demonstrated successfully [4–6].

A simple method to read the wavelength of the sensor FBG is by using only one FBG filter as interrogation component, and one PD to receive the signal filtered by the FBG filter. But the interrogation range which is too small for the bandwidth of a common FBG is normally only 0.2–0.3 nm. And for one received signal intensity, the sensing system could give out two wavelength reading values, one located at the left of the center wavelength of the FBG filter and another located at the right of it. This is the so-called dual-value problem, which cannot be discriminated by the system itself.

In Ref. [7], we had first proposed two parallel matched grating demodulation methods and researched them both theoretically and experimentally, which has also been reported by Ref. [8]. However, both of them

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cannot discriminate the cross-sensitivity effect. In this paper, the demodulation method by two parallel matched gratings was further researched, and a novel FBG sensing system with a parallel matched grating demodulation method based on the former project was designed. One of the interrogation gratings has the same encapsulation type and was located in the same thermal environment as the sensor grating. Thus, both of them will be affected by temperature variation, but the interrogation grating wavelength is not affected by strain. Under these conditions, this interrogation grating plays the role of temperature compensation grating simultaneously, and the wavelength shift induced by temperature and strain will be discriminated by signal processing. This sensing system not only holds the advantages of the former two parallel matched grating demodulation method, but was also able to discriminate the cross-sensitivity effect synchronously. The influence of the three FBG parameters on the interrogation range and precision was discussed. Besides, one of the interrogation gratings, whose center wavelength can be tuned, is pasted on a temperature controller. It seems that the whole system becomes more complex by introducing the temperature controller; it can ensure that the influence of the environment temperature on the dynamic range of the sensor system is avoided. The function of the temperature controller will be discussed in detail in Sections 3 and 4.

The sensing system proposed in this paper explored the potential of two parallel matched grating demodulation methods, and will play key roles in the applications of FBG sensors in real engineering circumstance.

2. Operation principle

The schematic diagram of the FBG sensor system based on two parallel matched grating demodulation methods is shown in Fig. 1. Light from a broad-band source transmits to couple C1, and then to the sensor FBG (FBGS); the reflected part of the light is transmitted to C1 again and is split into two beams by couple C2. One of the two beams transmits through couple C3 and reaches interrogation grating FBG1, then is reflected to photo-detector PD1; another one transmits through couple C4 and reaches interrogation

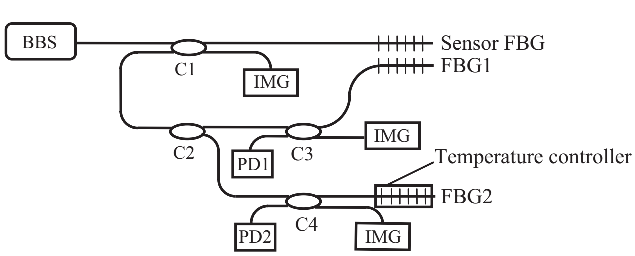

Fig. 1. Schematic diagram of the FBG sensor system.

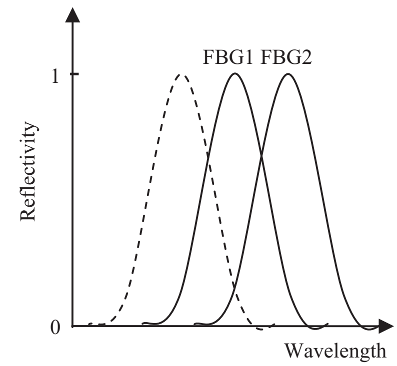

Fig. 2. Schematic spectra of the FBGs.

grating FBG2, then is reflected to photo-detector PD2. FBG1 and FBGS are located in the same thermal circumstance and both of them are affected by circumstance temperature (but FBG1 is not affected by strain). FBG2 is pasted on a temperature controller, whose wavelength could be adjusted by a temperature controller.

One key consideration for the preceding sensing system is that the center wavelengths of the three gratings must be chosen carefully and should match with each other. The center wavelengths of the FBGs are chosen according to the range of the measurands, and they set the instance only with a positive strain. For example, three gratings must satisfy the following relation: $\lambda_s < \lambda_1 < \lambda_2$. Now theoretically, the reflect spectra of the interrogation gratings and the sensing grating are shown in Fig. 2, where the real lines stand for the reflect spectra of interrogation gratings and the dashed line for FBGS. Suppose the center wavelength of FBGS augments gradually with the change of the environment (temperature or strain), then the output voltage values of the two detectors will change accordingly. One can solve the temperature and strain with these two voltage values. The following section will describe this process in detail.

3. Theory analysis

Now we will give the approach to solve cross-sensitivity effect and dual-value problem simultaneously through data processing.

Suppose the FBGs are isotropic and symmetrical, for the measurement of an applied longitudinal strain $\Delta\varepsilon$ when temperature is invariable, the wavelength shift $\Delta\lambda_{SS}$ is given by [9]

$$\Delta\lambda_{SS} = 0.78\lambda_B(\Delta L/L) = 0.78\lambda_S \cdot \varepsilon. \quad (1)$$

For the measurement of a temperature change ΔT, the corresponding wavelength shift $\Delta\lambda_T$ is given by

$$\Delta\lambda_T = \lambda_s(\alpha + \xi)\Delta T, \quad (2)$$

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