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# AN EXPERIMENT RESEARCH ON EXTEND THE RANGE OF FIBER BRAGG GRATING SENSOR FOR STRAIN MEASUREMENT BASED ON CWDM

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**Abstract**—According to the Coarse Wavelength Division Multiplexing (CWDM) wavelength dependent transmission characteristics, a wide range fiber Bragg grating (FBG) demodulation method is proposed and experimentally demonstrated in this paper. The relationship between system input and output is obtained through analysis, and verified experimentally. Particularly the influence of light source power on demodulation precision and calibration value is analyzed. The wavelength demodulation range of the system is about 10 nm, which can realize the measurement of 8000 με; The precision can be $3\sim5$ pm. Since the system is compact, low cost and passive, it is able to be integrated as a portable demodulation module.

## 1. INTRODUCTION

The advantages of optical fiber grating sensing are well known such as its anti-electromagnetic interference, small size (125 μm for bare optical fiber), light in weight, high temperature resistance (operating temperature limit up to 400°C–600°C), multiplexing ability, long transmission distance, corrosion resistance, high sensitivity, electrically passive operation, and easy for installation in any location [1, 2]. Since the first time Morey reported the optical fiber grating for sensing in 1989, the application on sensing for optical fiber grating has achieved sustained and rapid development [3, 11–14]. Here fibers with sensor arrays can be embedded into the materials to allow measurement of

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parameters such as load, strain, temperature, and tacked on a real-time basis.

Additionally, the prominent feature of Fiber Bragg Grating Sensors is that, the measurement signal is wavelength encoded, and is not sensitive to the intensity and the state of polarization. For this reason, the demodulation of coded wavelength is the core technology. The demodulation method can be divided into active and passive demodulation techniques according to the types of demodulation component. The former includes the interferometeric-based wavelength tracking techniques [4, 5], tunable laser-based wavelength tracking techniques [6], and tunable filter-based wavelength tracking techniques [7], and so on. The latter includes WDM-based and polarization maintaining fiber loop mirror-based wavelength tracking techniques [8], and so on. Compared with active demodulation techniques, the advantage of the passive demodulation techniques is low cost and fast-response, which has great utility in engineering practice. So far, a common disadvantage of the wavelength passive demodulation techniques is the small range, no more than 4 nm [9]. For the typical Bragg fiber grating, the strain sensitivity is 1.15 pm/με, which means the range can be measured is no more than 4000 με, making it not suitable for some special applications. This paper explored the possibility to extent the range of FBG sensor for strain measurement using nonlinear area of CWDM, and interference of light source. Particularly the influence of light source power on demodulation precision and calibration value is analyzed.

## 2. PRINCIPLE

Fiber grating is sensitive to both heating effect and strain effect, when temperature kept constant, the FBG is affected only by the axial strain, and then the axial strain can be expressed by the Equation (1).

$$\varepsilon_Z = \Delta L/L = \Delta\Lambda/\Lambda \tag{1}$$

The relationship between strain coefficient $\varepsilon_{ij}$ and material tensor $B_{ij}$ can be described by $B_{ij} = 1/\varepsilon_{ij} = 1/n_{eff}^2$, then

$$\Delta n_{eff} = -\Delta B_{ij} n_{eff}^3/2 \tag{2}$$

From (1) and (2), following formula can be concluded:

$$\Delta\lambda_B = 2\Lambda\left[-\frac{n_{eff}^3}{2}\cdot\Delta\left(\frac{1}{n_{eff}^2}\right)\right] + 2n_{eff}\Lambda\cdot\varepsilon_Z \tag{3}$$

We use a 1 × 2 Coarse Wavelength Division Multiplexing (CWDM) component as edge filter, which is based on thin film technology with high stability. Shift in the central wavelength can be changed into light intensity change, when it passes through the CWDM. Then the demodulation on wavelength shift caused by strain can be achieved [10], as shown in Fig. 1. Our research is based on the system shown in Fig. 2. In order to perform technical feasibility study on technical solution, we use tunable laser to simulate the signal reflection from the fiber grating. It is attenuated to −19 dBm, which is close to the optical power level of the real system. Before connected to demodulation system, its spectrum is shown in Fig. 3, when a wavelength is set. In order to eliminate the effect of power, we subtract two-way signal and enhanced with the chip AD620, then handle the voltage signal to data transmission circuit.

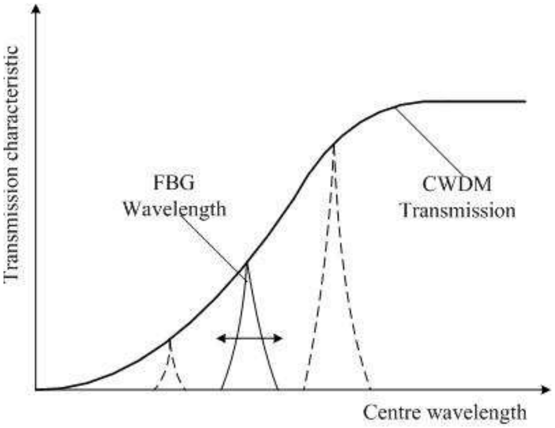


**Figure 1.** The relationship between the wavelength shift and the output ratio signal.

By using logarithmic amplifier(AD8304) amplifying

$$V_{LOG} = 0.2\log_{10}\frac{P_{OPT}}{P_Z}$$

where $V_{LOG}$ is the output voltage, $P_{OPT}$ is the input optical power, $P_Z$ is the reference power.

$$\Delta V = V_{LOG1} - V_{LOG2} = 0.2\log_{10}\frac{P_1}{P_Z} - 0.2\log_{10}\frac{P_2}{P_Z} = 0.2\log_{10}\frac{P_1}{P_2}$$

where $\Delta V$ is the voltage difference. The centre wavelength is scanned from 1533.700 nm to 1543.100 nm with step mode, and the sampling interval is 10 pm.

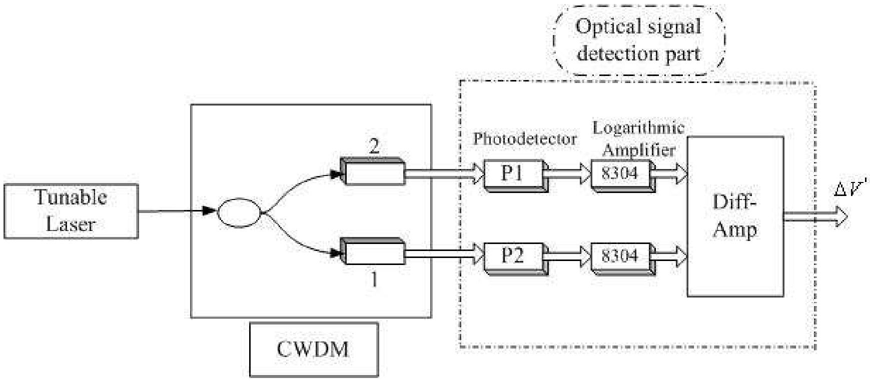


**Figure 2.** The optical signal demodulation system.

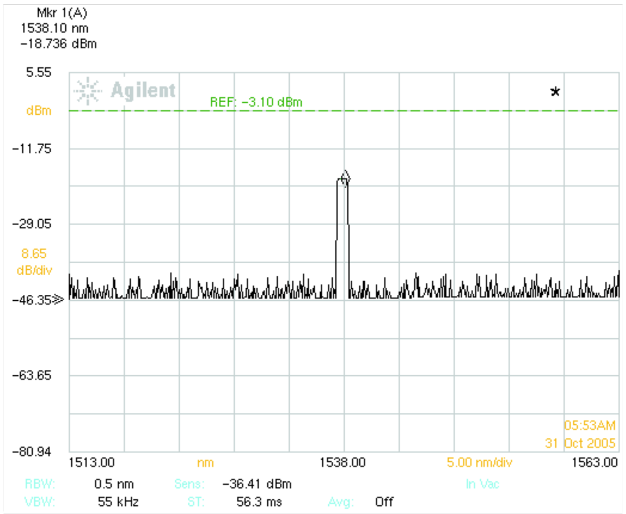
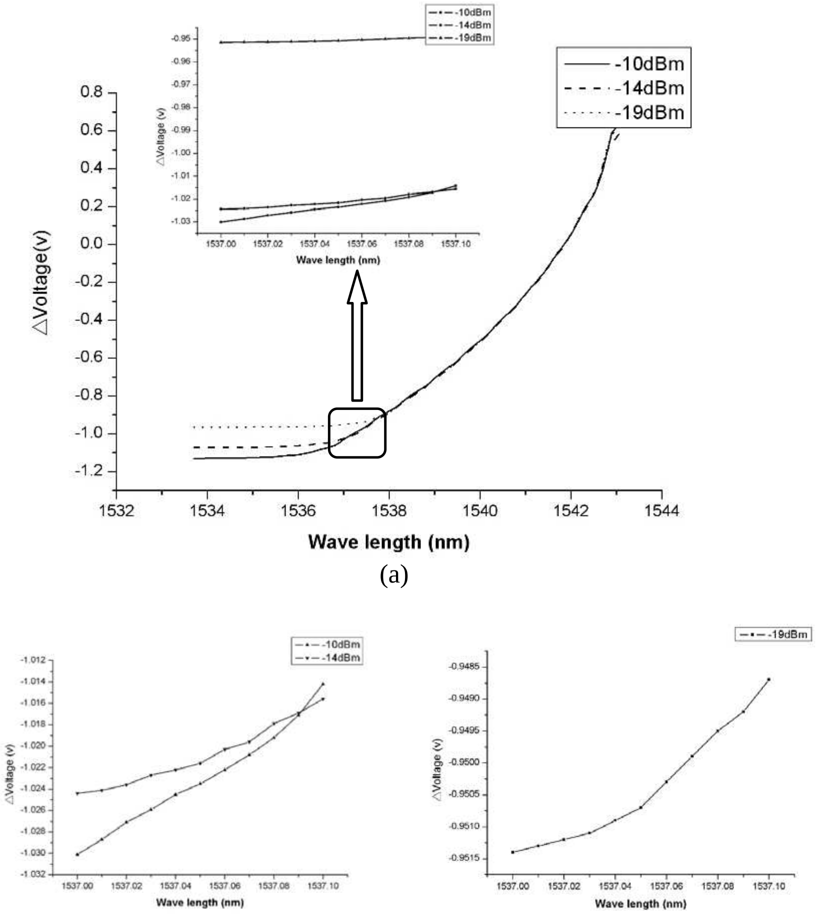


**Figure 3.** The output signal of tunable laser.

## 3. RESULTS

The measurement results is shown Fig. 4, when the powers of the signal are −10 dBm, −14 dBm and −19 dBm, respectively. It can be seen that, they are nearly the same on the wavelength between 1538 nm and 1543 nm, but are differ markedly on the wavelength between 1533.7 nm and 1538 nm. As a result, the relationship between $\Delta V$ and the reflected center wavelength need to be calibrated separately under different power, if we want to use the wavelength between 1533.7 nm and 1538 nm to extend measurement range. And, the resolution is also different.



(a)

(b) (c)

**Figure 4.** Wavelength from 1533.7 nm ~ 1543.1 nm.

The insert map of Fig. 4(a) shows the local result from 1537.00 nm to 1537.10 nm, and the more detailed information are shown in Fig. 4(b) and Fig. 4(c). The two conditions when the power is −10 dBm and −14 dBm are close as is shown in Fig. 4(b). So if the resolution is 5–10 pm, the systematic noise should be less than 1 mv, to deliver signal to noise ratio at 1:1. When the power of the signal attenuated to −19 dBm, the sampling point undergoes large departures as is shown in

Fig. 4(c), if the resolution is 10 pm, the systematic noise should be less than 0.3 mv, to deliver signal to noise ratio at 1:1, which is obviously hard to achieve. Average every 100 sampling points is needed, and then the systematic noise need to be kept not exceeding 0.3 mv.

## 4. CONCLUSION

An expand method on FBG demodulation based on CWDM technology is proposed and experimentally demonstrated in this paper. The relationship between system input and output was obtained through analysis, and the relationship was verified experimentally. Particularly the influence of light source power on demodulation precision and calibration value is analyzed. When the power of narrowband optical signal is more than −14 dBm, we can get a better resolution and keep the high speed performance at the same moment.

## ACKNOWLEDGMENT

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