ISSN : 0974 - 7435 Volume 10 Issue 19

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(19), 2014 [11549-11555]

Research on the monitoring method of fiber bragg grating seismic waves

Guang Ding
Earthquake Administration of Jilin Province, Jilin, 130117, (CHINA)

ABSTRACT

There are many monitoring methods of Fiber Bragg Grating (FBG) seismic waves. From the perspective of the construction of its detection system, unbalanced M-Z waveguide demodulation affects the construction of the detection system. Then, the collected data are effectively analyzed by the computer to achieve the specific graphic of seismic waveform. During the analysis and simulation of unbalanced M-Z waveguide demodulation, the phase modulator is effectively demodulated, so it will be set by the modulation depth and modulation frequency. Therefore, waveform graph is confirmed because seismic wavelength does not migrate. Besides, 3*3 coupler demodulation seismic detection system constructs the formation path of arrayed FBG seismic waves. The formation process of seismic waves can be more vivid by its simulation process, achieving the aim of monitoring more comprehensively to the seismic waves. Through the above research process, the monitoring process of FBG seismic waves becomes more effective and distinct, and the science of the monitoring process can be fully guaranteed. Moreover, the research and exploration of this paper further develops the monitoring methods of FBG seismic waves, laying a solid theory foundation for the future studies. Meanwhile, this paper also promotes to improve continuously the effectiveness of the formation process of seismic waves.

KEYWORDS

Fiber bragg grating (FBG); Seismic wave detection; System construction; Method exploration.

INTRODUCTION

The detection process of seismic waves is very complicated. During the monitoring of FBG seismic waves, there are a great many of ways to be adopted. Combined with the main methods and the construction of detection system, this research carries out related studies and explorations. The detection system of seismic waves based on unbalanced M-Z waveguide demodulation is analyzed validly, and the construction of its simulation system is discussed, laying a solid theory foundation for the construction of the detection system. Moreover, the monitoring system of seismic waves based on 3*3 coupler demodulation is analyzed and discussed validly, and the construction of its simulation system is effectively discussed. Combined with these discussions, the research and analyzing logic is more distinct, contributing to improve the monitoring method of FBG seismic waves.

THE ANALYSIS OF THE MONITORING SYSTEM OF SEISMIC WAVES BASED ON UNBALANCED M-Z WAVEGUIDE DEMODULATION

Figure 1 is the basic idea about the monitoring method of seismic waves. It can be seen that the system is pulse modulated to the pulsed light whose period is t by SLD. The pulsed light goes through the fiber optic ring resonator to the sensor fiber. There are a number of sensor heads in the sensor fiber, the total length of which is 10 km, and the distance between each sensor head is 250 m. Every sensor head is encapsulated a grating whose spectral width is δλi. The spectral widths of the reflective spectrum of gratings encapsulated in sensor heads are superposed to meet $\sum \delta\lambda i \leq \Delta\lambda$. After optical pulses gradually reaching each grating, the reflected light will return to the ring resonator according to the original order, and finally will enter into unbalanced guided wave instrument, forming the interference signals. The formation of the signals includes some array sensor information which influences the interference signals through changing the wavelength. Moreover, the information intensity of the collected interference signals is outputted effectively through the photoelectric conversion circuit. Afterwards, the modulation amplitude and modulation intensity of the signals are controlled by the phase modulator demodulating the output intensity of the interference signals. The output frequency is much stronger than the signals' frequency. The signals shown in the photoelectric integration instrument are superposed, when the signals will be located by the sensor heads. Every superposing signal corresponds to a sensor head, which keeps the equal time distance between the maximum values and sensor heads, so the information can be given a feedback to the computer. On the basis of the signal feedback, the specific data collected in the process of photoelectric conversion and the information shown in the photoelectric integrated instrument are computed and organized to confirm the seismic waveform.

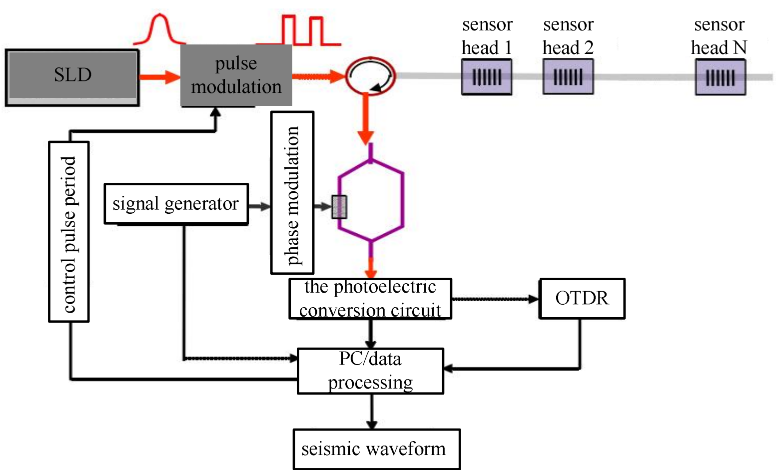

Figure 1 : The real-time monitoring system of array FBG earthquake based on unbalanced waveguide M-Z interferometer

When this system does not monitor the seismic wave, it transmits effectively only one light pulse in every repeated period, forming according reflective spectrum in the sensor heads of the system. Therefore, the actual distance between sensor heads in the reflective spectrum can be computed, and then the interval can be computed and transmitted into the related system. Figure 2 (a) is a reflective spectrum, which is the actual distance between sensor heads. In the process of no seismic waves, the center wavelength can be marked as λ_i, whose value range is any value from 1 to N. After monitoring the seismic waves, profit influences the grating, making the center wavelength change accordingly. Figure 2 has shown it. In the derivation process, it can be concluded that the migration which the center wavelength makes can change light intensity accordingly, from Ii to I'i. The first seismic waves sample is collected by the photoelectric conversion. The processes will have increased with the increasing number of pulsed light. Therefore, the acquirement of seismic waves can be obtained by light intensity, and be processed during the related conversions. Its work will be operated periodically. The computer gathers and analyzes the related information so that the period of the pulsed light can be modulated effectively. If the distance between the sensor heads reaches 250m, the location will be set correctly beyond 250m for the system. The resolution is mainly decided by the pulse width, so the confirmation of the pulse width can be computed by W=2nδ/c=2.5μs. In this process, only one light transmits. While for each group of information collection, the repeated period can be computed from the fiber's characteristic, and then the repeated period which is t=2nL/c=0.1ms can be derived. The repeated frequency keeps at 10 kHz in the system. During the transmission of the seismic waves, low frequency wave rate is the main transmitting method, varying from a few Hz to more than a hundred Hz. Moreover, the repeated period takes a long time. But the repeated period for the system can only be t, much shorter than the transmission period of the seismic waves T. During the information collection of the wavelength, through gathering and analyzing the information of the system, the specific frequency of the seismic waves and the intensity can be analyzed and got the final result. Through the restriction of laying fiber optic cable, the round trip of the optical pulse in the system takes 0.1ms. The sample points which can be acquired are 100 in a repeated period for the seismic wave whose frequency is 100 Hz. The actual curve in the process of the seismic waves obtaining the sample points can be seen in Figure 3. Q represents the specific intensity of the tested seismic waves in this process.

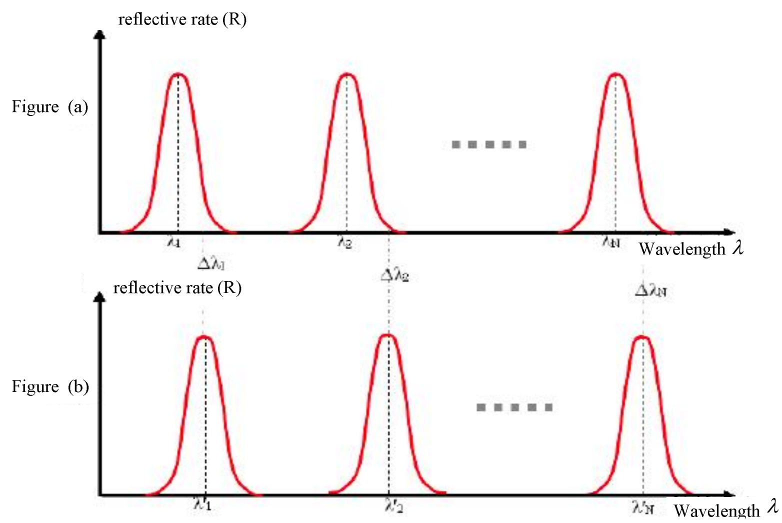

Figure 2 : The comparison of the reflective spectrums before and after the functions of the sensor heads array seismic waves

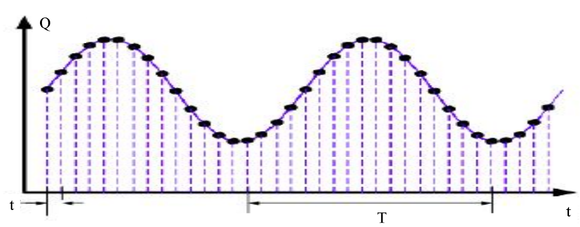

Figure 3 : The curve of the collection of the seismic waves

During the detection of the seismic wave amplitude, it can be acquired by utilizing N gratings. After checking and verifying, the distribution of its dimension intensity can be obtained. In the process of setting up the sensors, p light waves in x and y direction are perpendicular and s wave in z direction are perpendicular with p waves. It is possible to acquire the specific three dimension intensity of the seismic waves at different time intervals and ensure that the accuracy of the epicenter direction and spreading range has been increased constantly. However, too much seismic information shall be acquired in this process and the range of search of time is too wide. But in the process of collecting seismic information in the way of unbalanced wave guide interference wavelength modulation, the sensitivity and real-time performance can be ensured much well, so the measurement of the seismic wave intensity can be more accurate.

THE ANALYSIS AND SIMULATION OF UNBALANCED M-Z WAVEGUIDE DEMODULATION

The most distinguished feature of unbalanced M-Z waveguide demodulation is adopting the unbalanced M-Z phase modulator of the waveguide construction to generate two complementary interference signals, whose the theory is shown in Figure 4.

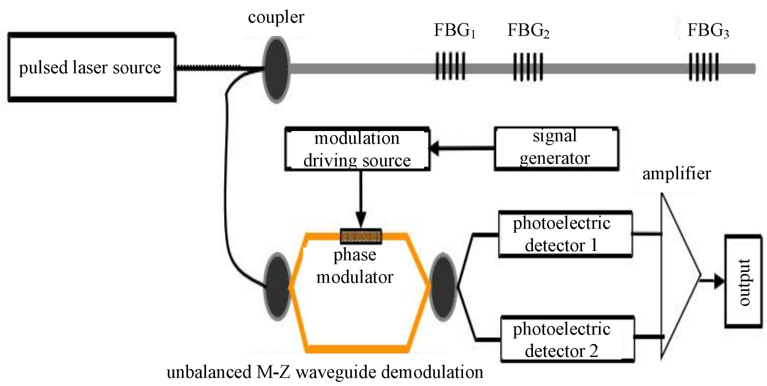

Figure 4 : The schematic diagram of unbalanced M-Z waveguide demodulation

Hypothesize the reflective signal of FBG array through unbalanced M-Z waveguide demodulation to become two signals as following:

$$\begin{cases} I_1(\lambda,t) = A\{1+k\cos[\varphi(\lambda)+\Phi(t)]\} \\ I_2(\lambda,t) = A\{1-k\cos[\varphi(\lambda)+\Phi(t)]\} \end{cases} \quad (1)$$

A represents the interference signal amplitude; k is the visibility of interference fringes; φ (λ) is the phase difference generated by asymmetric waveguide, and φ (λ) =2πnd/λ, and (1-3) equation was set up. Φ (t) represents the phase varied from time. Because adopting the waveguide construction, the stability of the phase of the system increases a lot, decreasing the effect of the random phase fluctuations caused from the instability of the system. But for the stability of the signals output waveform and the convenience of processing signals, the phase modulator is added in an interference arm to generate PGC. Suppose it as simple sinusoid. So:

$$\begin{cases} I_1(\lambda,t) = A\left\{1+k\cos\left[\dfrac{2\pi nd}{\lambda}+\alpha\sin(wt)\right]\right\} \\ I_2(\lambda,t) = A\left\{1-k\cos\left[\dfrac{2\pi nd}{\lambda}+\alpha\sin(wt)\right]\right\} \end{cases} \quad (2)$$

In the above two formulas, a represents the depth during the phase modulation, and w is the specific frequency during the phase modulation. Although wavelength and phase modulator have some negative effects on it in the process of phase modulation, the frequency variation is much slower than the modulation frequency, which is an actual performance of slowly varying signal. During the simulation and analysis of two signals, suppose their wavelength is 1,550 nm, and the length difference of interference arms is 2μm, and the modulation frequency of phase keeps at 50 kHz, and the modulation depth is 2π. Under the circumstance of no signals, the waveform graph when the wavelength does not migrate can be represented in Figure 5 to Figure 8.

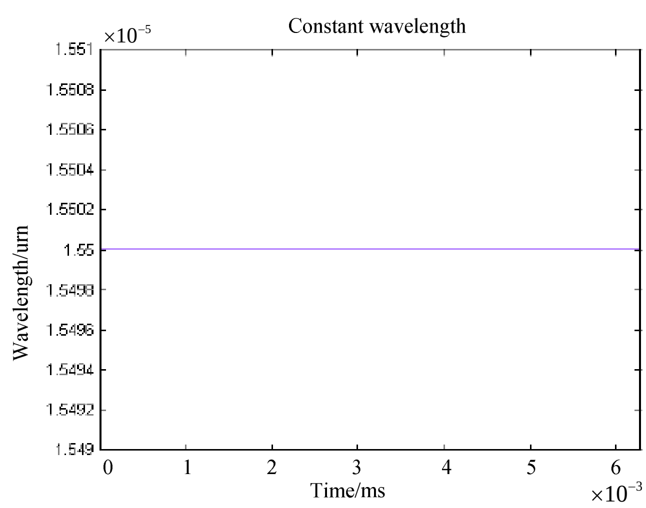

Figure 5 : Wavelength change with time

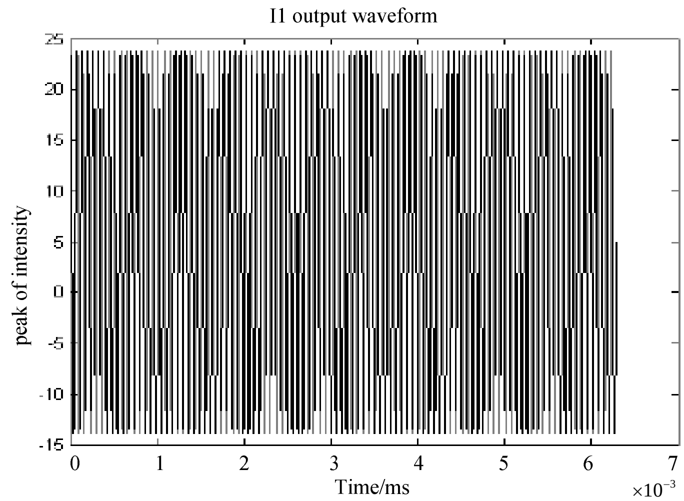

Figure 6 : I1 output waveform at constant wavelength

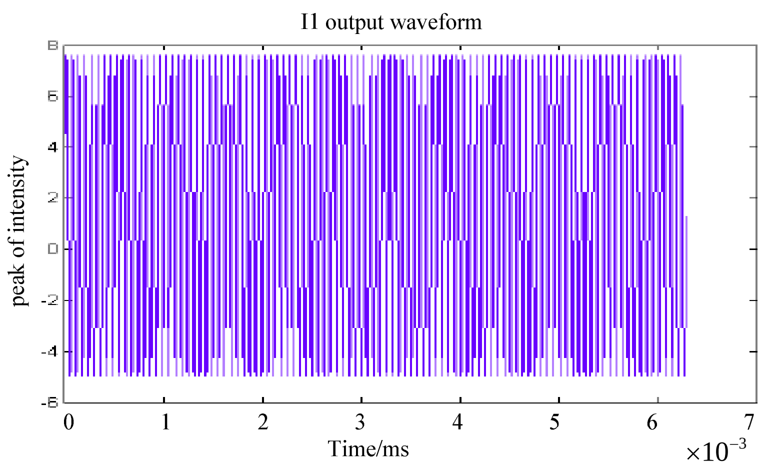

Figure 7 : I2 output waveform at constant wavelength

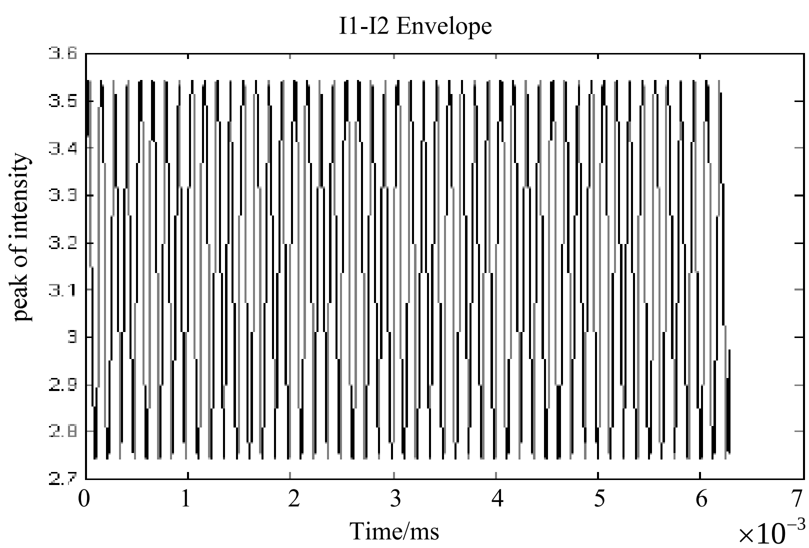

Figure 8 : I1-I2 waveform at constant wavelength

It can be seen from Figure 5 that the wavelength does not change accordingly. The waveform of I1 has fully shown in Figure 6, and formed envelope waveform with the signals in Figure 7 and Figure 8 which are complementary with I1. It can be found from above four Figures that the output process of two signals both keep at the relatively stable situation, so the form they showed can be presented by a line.

THE ANALYSIS OF THE MONITORING SYSTEM OF SEISMIC WAVES BASED ON 3*3 COUPLER DEMODULATION

The system of this plan is shown in Figure 9. The wide spectrum laser source lauched by SLD is modulated to become the pulsed light whose period is t by going through LiNbO3 EO Intensity Modulator, transmitting to the fiber optic ring resonator then entering into the sensor fiber. There are N sensor head arrays based on FBG installed in series in the sensor fiber. The sensor head is encapsulated N FBGs (Gi, i=1~N) which have different reflective center length. The spectral width of every grating is $\delta\lambda i$. N spectral widths of the reflective spectrum of FBG are superposed to meet $\sum\delta\lambda i \leq \Delta\lambda$. After optical pulses gradually reaching each grating, the reflected light will return to the ring resonator according to the original order, and then enter into unbalanced M-Z fiber interference instrument based on 3*3 couplers, which is the array FBG seismic waves monitoring system based on 3*3 coupler demodulation.

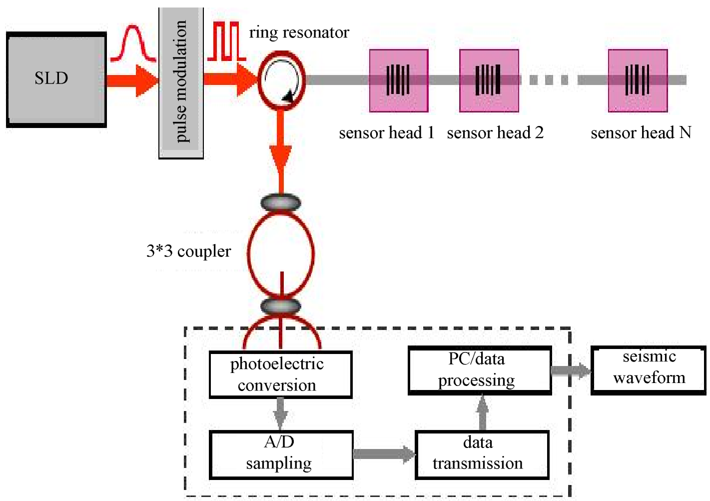

Figure 9 : The real-time monitoring system of array FBG seismic waves based on 3*3 coupler demodulation

When the seismic waves do not affect the system, the transmitted optic pulse in the system is few in every stipulated interval. The reflective spectrum appears at the sensor head array, whose distance is measured by the distance between sensor heads. And they are arranged in order to the wavelength demodulation system. The wavelength demodulating procedures are referred to 3*3 coupler. Because the intensity of output light is affected by the migration of wavelength, light sampling is realized by the photoelectric conversion. Under the continuous influences of the optic pulse, the seismic waveform which has transferred into light intensity is collected, and then the output light intensity is processed in a special unit by photoelectric conversion. If there is an appropriate pulse width of optic pulse, its repeated period t can be confirmed by the round-trip time of light from optic pulse to the end. If the seismic wave period T is much longer than the repeated period t, the monitored seismic waveform is much more reliable. The intensity and frequency of the seismic waves can be inferred from the former received information. The total length of the fiber which the system is estimated to install is 10 km, so it also restricts that the interval from the reflective grating spectrum to the photoelectric conversion circuit is 2.5μs and the distance between sensor heads is 250 m and the pulse interval is 0.1ms. The interference signal launched by the system shall be tested by the photoelectric conversion circuit. The change of the displacement of FBG center wavelength caused by the seismic waves influences the intensity of the interference signal. In other words, the frequency width of the seismic waves is equal to the measured signal bandwidth, which is more than a hundred Hz. So the frequency width of the seismic waves must be smaller than the preset signal bandwidth of the circuit. The interval between the reflective spectrum and the tested circuit is 2.5μs, which requires that the sampling frequency of the photoelectric circuit is no less than 0.4MHz.

The circuit design of the system is showed in the dashed box in Figure 9. The interference signal is outputted by 3*3 coupler. The photoelectric conversion is realized by the photodiode. A/D sampling is done after amplifying the signals. Before transmitting to the computer, the signals shall be changed into serial ports signals. Three groups of signal intensity information outputted by coupler is the representation of signal sequence on the computer. The seismic wave information is demodulated by the phase stepping algorithm.

THE SIMULATION AND EXPLORATION BASED ON 3*3 COUPLER DEMODULATION

A.D.Kersey was successful to demodulate FBG wavelength by utilizing unbalanced M-Z interference instrument constructed by two 2*2 couplers in 1933. Afterwards, many scientists have improved the inteference demodulation, so its comprehensive performance has improved a lot. In 1994, A.Dandridge and some other scientists succeeded to demodulate the fiber wavelength by the means of 3*3 coupler wavelength demodulation. FBG wavelength demodulation through 3*3 coupler was applied by Huang Chong and other scientists in 2005. They processed the output signals from the photoelectric conversion by using the phase unwrapping algorithm. The results include that the range of strain measurement is 2014με, and the dynamic resolution is 27nε/ (Hz) 1/2. So the accuracy of the wavelength demodulation is 1pm. Figure 10 is its system schematic.

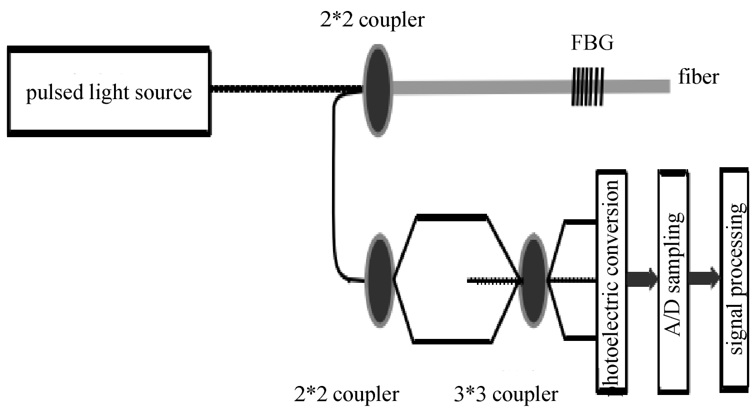

Figure 10 : The schmatic of FBG wavelength demodulation through M-Z interference instrument based on 3*3 coupler

CONCLUSION

The above content is the related reserches and discussion which this paper studied combined with the monitoring method of FBG seismic waves. This paper mainly analyzes the construction and simulation of two systems. Then the necessary elements during the formation of the seismic waves are explored in this paper. Moreover, the construction path of the system has been studied, so the theoriticalness and practicalness of the monitoring method of FBG seismic waves have been reflected.

REFERENCES

[1] Tan Yiqiu, Wang Haipeng, Ma Shaojun, Ji Lun; Asphalt pavement compaction monitoring based on fiber grating sensing technology, China Journal of Highway and Transport, **27(5)**, 112-117 **(2014)**.

[2] Lu Zhaohui, Hu Yelin; Analysis of cable temperature test based on the optical fiber grating temperature, Cryo.& Supercond, **42(7)**, 90-92 **(2014)**.

[3] Gao Yufei, Liu Chao, Zhang Yong; Reasearch on transmission power spectrum of titled fiber bragg grating temperature sensing, Optical Technology, **(4)**, 327-330 **(2014)**.

[4] Zhang Fengwei, Chen Xiaoyong, Song Weibin, Li Yingna, Li Chuan; Earth-rock dam monitoring system based on fiber grating sensing network, Optical Technology, **(4)**, 357-361 **(2014)**.

[5] Deng Yuanshi, Liu Fenglian, Wu Chi, Yang Lin; Application of fiber bragg grating device in icing monitoring system of transmission lines, Insulators and Surge Arresters, **(3)**, 39-43 **(2014)**.

[6] Zhang Jingchuan, Chen Dewang, Wang Lijuan; Research of fiber grating wavelength-temperature fitting based on bic criterion for model selection, Chinese Journal of Sensor and Actuators, **27(2)**, 217-219 **(2014)**.

[7] Wen Changjin, Li Yulong; Prestress capilary encapsulating device of fiber bragg grating, Optical Communication Technology, **38(6)**, 12-15 **(2014)**.