Fiber Bragg grating sensing system based on code division multiple access

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A novel fiber Bragg grating (FBG) sensing system based on code division multiple access (CDMA) technology is proposed. CDMA is used to separate each reflected sensor. Simulation of experimental results indicates the CDMA technology combines with optical fiber grating sensing system together successfully. Furthermore, the system using semiconductor optical amplifier (SOA) is experimented. The experimental results show that theory and simulation are correct.

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Among the different multiplexing techniques of fiber Bragg grating (FBG) sensors, the wavelength-division multiplexing (WDM) technique is widely used[1−5]. The maximum number of multiplexed sensors is limited by the width of the broadband (or wavelength-scanned) light source and the Bragg wavelength operation ranges required by the FBG sensors. Another technique is the time-division multiplexing (TDM) technique[6,7], where a pulsed source is used to illuminate the gratings placed at different distances from the source. The reflected signals from the gratings are separated in time domain. These pulses arrive at a time determined by the distance between interrogator and FBG sensor, and one FBG sensor can be distinguished from another by analyzing the pulse arrival times. This imposes a limit on the sensor detection speed, number of sensors, and maximum distance between sensors.

We propose a scheme which using code division multiple access (CDMA) in this letter. The system utilizes the autocorrelation property to separate individual sensors from the multiplexed output of many sensors. To identify each sensor, a pseudo-random binary sequence (PRBS) code is sent as a random signal into the FBG sensor array, and the information of the corresponding sensor is decoded in the electrical domain. Simulation of experimental results indicates the CDMA technology combines with optical fiber grating sensing system together successfully. Furthermore, the system using semiconductor optical amplifier (SOA) is set up.

The proposed conceptual diagram of a CDMA sensor network is shown in Fig. 1. To cover the whole wavelength band of all sensors, a broadband light source was used. The broadband source was directly modulated by using PRBS codes. The modulated optical signal from broadband light source was amplified by using erbium doped fiber amplifier (EDFA) and went through FBG sensors via circulator. The FBG sensors were used for measuring strain sensitivity.

When the modulated optical signal experienced FBG sensor array, the optical signal which was consistent with center wavelength of FBG sensors was reflected and added from each sensors. The optical signal was converted into electrical signal by using photodetector (PD). Then, the signal was correlated with delayed PRBS code that have the same data pattern. At the end, the result was monitored by an oscilloscope. There are two peak values in the output traces of the integrator, which correspond to the signals reflected from each sensor and vary according to the applied strains. Variations of peak values were measured by use of an oscilloscope.

In the experiment, we assumed two kinds of circumstances. One is that two FBG sensors have the different center wavelengths and different reflectivities. Two FBG sensors were used for a simple demonstration of applied strain. The center wavelengths of the sensors were 1 551.8 and 1 552.6 nm respectively. The bandwidth of each sensor was 0.2 nm and the reflectivity of each sensor was 90% and 50%, respectively. Figure 2 shows the spectral responses of Bragg grating sensor 1 and sensor 2.

The other kind of circumstance is that the two FBG sensors have the same center wavelength. The theoretical model of spectral responses is Fig. 3, because they have the same center wavelength. The spectral responses of two FBG overlap is in practice. Figure 4 shows spectral responses of Bragg grating sensor 1 and sensor 2 by oscilloscope without CDMA. We could not separate which spectral responses of Bragg grating is sensor 1 or sensor 2. But in our experiment, autocorrelation method was used to separate each sensor.

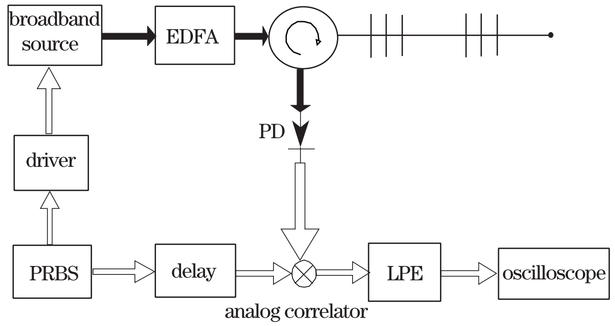

Fig. 1. FBG sensing system using CDMA.

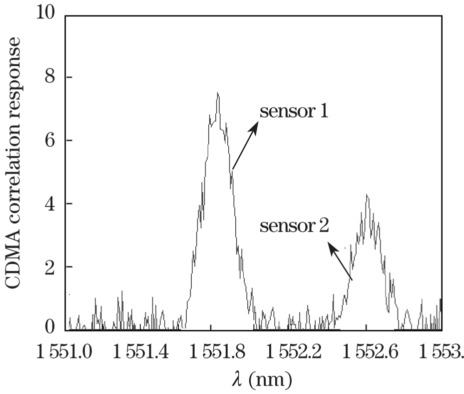

Fig. 2. Spectral responses of Bragg grating sensor 1 and sensor 2.

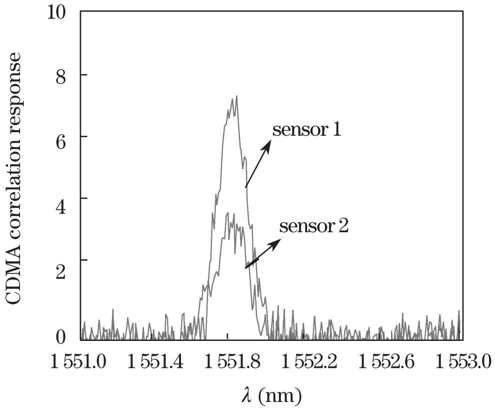

Fig. 3. Theoretical model of spectral responses for Bragg grating sensor 1 and sensor 2.

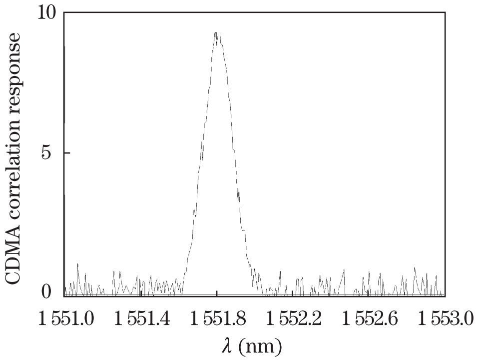

Fig. 4. Spectral responses of Bragg grating sensor 1 and sensor 2 by oscilloscope.

In the experimental setup of a multi-FBG sensor system, field programmable gata array (FPGA) generates PRBS. The PRBS generator makes a sequence by using an m-stage linear feedback shift register generator. The sequence length is $2^m - 1$. It indicates that the number of FBG sensors is $2^m - 1$. Every sensor has its own PRBS.

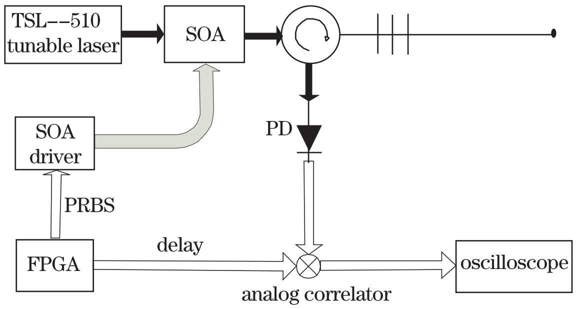

Fig. 5. Experiment setup of proposed sensor network.

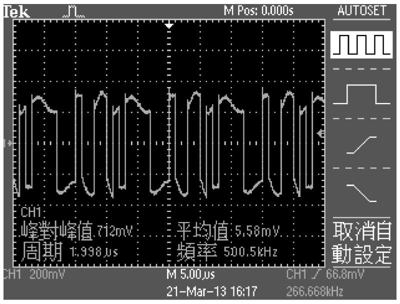

Fig. 6. (Color online) Reflected light of the FBG.

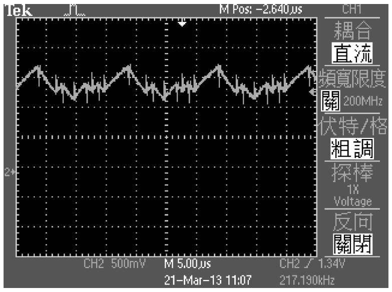

Fig. 7. (Color online) Correlation value of sensor.

It consists of a 4-bit shift register and exclusive-or gates, and the maximal length of the PRBS $(2^4 - 1)$ is used. We use only one FBG. The center wavelength of FBG is 1 294.2 nm, and the reflectivity of the sensor is 90%. Figure 5 shows the schematic diagram of proposed FBG sensor network. The tunable laser (TSL-510) as a light source was driven at 200 mA of bias current by SOA driver and it is modulated by using PRBS code from FPGA. Figure 6 is the reflected light of the FBG. Then, the reflected signal was multiplied with another 15-bit PRBS code that has the same data pattern as modulation signal. At the end, the result was monitored by an oscilloscope. The autocorrelation pulses were obtained as shown in Fig. 7.

In conclusion, a FBG sensor network based on CDMA and its simulation are shown. Firstly, we use two FBGs with different center wavelengths and reflectivities for a simple demonstration of applied strain. The simulation proves the correctness of the theory based on CDMA. Secondly, we use two FBG with same center wavelength and different reflectivity. In this experiment, the autocorrelation method of CDMA is used to separate each sensor. At last, the system using semiconductor optical amplifier is experimented. The experimental results show that the theoretical result agree well with the experimental data.

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References

1. Y. Rao, D. J. Webb, D. A. Jackson, L. Zhang, and I. Bennion, J. Lightwave Technol. **15,** 779 (1997).
2. J. M. Gong, J. M. K. MacAlpine, C. C. Chan, W. Jin, M. Zhang, and Y. B. Liao, IEEE Photon. Technol. Lett. **14,** 678 (2002).
3. R. D. Feldman, J. Lightwave Technol. **15,** 1823 (1997).
4. R. D. Feldman, E. E. Harstead, S. Jiang, T. H. Wood, and M. Zirngibl, J. Lightwave Technol. **16,** 1546 (1998).
5. J. B. Stark, M. C. Nuss, W. H. Knox, S. T. CundiffR, L. Boivin, S. G. Grubb, D. Tipton, D. DiGiovanni, U. Koren, and K. Dreyer, IEEE Photon. Technol. Lett. **9,** 1170 (1997).
6. D. J. F. Cooper, T. Coroy, and P. W. E. Smith, Appl. Opt. **40,** 2643 (2001).
7. D. J. F. Cooper and P. W. E. Smith, J. Lightwave Technol. **21,** 1612 (2003).