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Study on FBG Wavelength Demodulation System with the Continuous Dynamic Scanning of Tunable DFB Laser

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Abstract

A FBG wavelength demodulation system based on the continuous dynamic scanning of tunable distributed feedback (DFB) laser is put forward and implemented. First, this paper introduces the basic principle of FBG wavelength demodulation system; second, the demodulation algorithm as the key of whole system is realized and compiled into DLL files by using the C programming language, then the Labview program calls for DLL files through a dynamic link library to establish a data processing program, including a interactive data processing interface. Not only it improves the accuracy of FBG wavelength demodulation system, also it helps the subsequent development on the system even though the hardware equipments keep invariant. The results show that the demodulation system has a fine resolution and stability, which can meet the practical requirements and be suited to produce in business and put into use in the engineering.

Keywords: *FBG, demodulation, DFB, LabView*

1. Introduction

Since Morey first reported the fiber Bragg grating (FBG) is used as the sensor in 1989, FBG sensing has received extensive attention worldwide and developed rapidly [1-3]. FBG sensors are capable of measuring the various physical parameters, such as pressure, temperature and strain, *etc.*, [4, 5]. In a general way, the center wavelength of FBG reflected light keep a good linear relationship with the variation of physical quantity outside. So long as FBG wavelength is identified, the variation of physical quantity outside can be calculated accordingly. So FBG wavelength demodulation technology has a critical impact on FBG application [6, 7]. Currently, many demodulation methods have been put forward [8-11], but the most of them have the problem of low light utilization, high cost and unsuited to produce in business.

This paper proposes and implements a FBG wavelength demodulation system based on the continuous dynamic scanning of tunable distributed feedback (DFB) laser [12]. It solves the problem of low light utilization and high cost. And the composition of whole system is compact, which is suited to produce in business. Through the establishment of data processing program based on LabVIEW and VC++6.0, the collected experimental data is optimized to process [13]. Meanwhile, an interactive user-friendly operator interface is provided, which is very concise. So it is more convenient for operator to operate and process the data. The results show that the demodulation system has a fine resolution and stability, which can meet the practical requirements. Furthermore, the key of whole system focuses on the algorithm. When the algorithm is improved, the property of whole system will be

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improved accordingly even though the hardware equipments keep invariant. It is advantageous for the optimizing and developing afterwards.

2. System Principle

The FBG wavelength demodulation system scheme based on the continuous dynamic scanning of tunable DFB laser is shown in Figure 1. It mainly consists of five parts: the tunable DFB laser, the sensing FBG and the Fabry-Perot (F-P) etalon, the photo detector and the amplification circuit, the data acquisition card, the data processing program on PC.

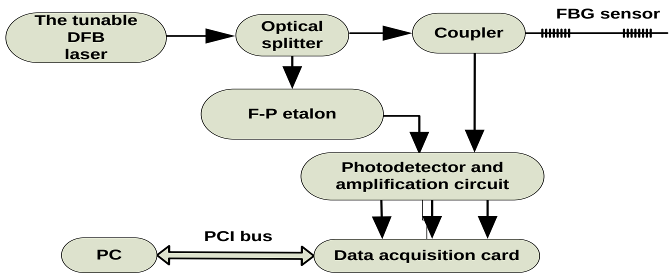

Figure 1. The Demodulation System Scheme

At different moments in a scanning period, the tunable DFB laser emits narrowband laser with different wavelength. The wavelengths and the scanning time points have a linear relationship approximately, as shown in Figure 2. The range of wavelength scanning is from 1550.012nm to 1554.812nm.

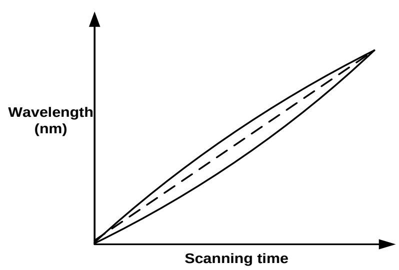

Figure 2. The Relationship between Wavelength and Scanning Time of DFB Laser

The tunable DFB laser emits a narrowband laser. Through the optical splitter, two beams obtained enter into the F-P etalon and FBG sensor separately. Since the F-P etalon allows the light with certain wavelength to pass, the transmitted light intensity of F-P etalon varies with time to form peaks and troughs serially. Then the light signal is converted to the electrical signal by the photodiode. At last the electrical signal amplified by the amplified circuit is sampled by A / D converter. It is shown in Figure 3.

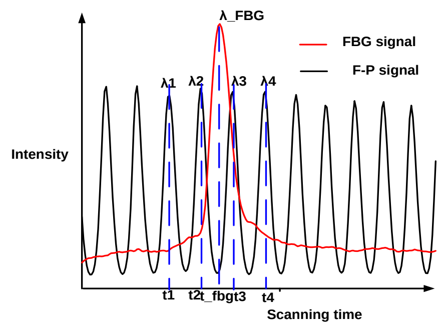

Figure 3. The Time Domain Signal of F-P Transmission Spectrum and FBG Reflected Spectrum

The other beam entering the FBG sensor is reflected when it meets the Bragg condition. Then it is converted to the electrical signal and amplified by the photodiode and the amplifier circuit. It is shown in Figure 3. Both the electrical signals are collected by the digital processing board. At last the data given by a text is done by the data processing program on PC.

We can get each time point [tn] corresponding to each peak of F-P etalon transmission spectrum by the Peak-Detection algorithm [14-16]. Due to the transmitted light wavelengths of F-P etalon are known, the array of wavelengths and time points [λn][tn] is fitted by the binomial fitting algorithm to get the wavelength versus time curve $\lambda = f(t)$ [17], as shown in Figure 4.

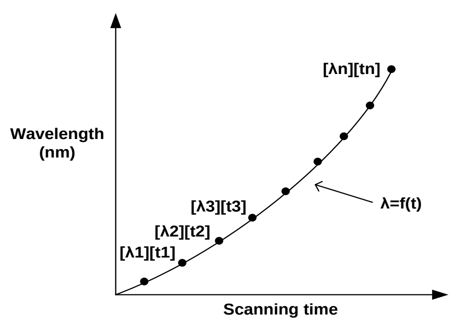

Figure 4. The Wavelength-Time Curve of Scanning Laser

Since the light entering the F-P etalon and FBG is isolated from a beam, they have the same wavelength-time curve. From Figure 4, we can see that the center wavelength of FBG reflected light can be calculated by the expression when the time point t_fbg is known. We can get the time point t_fbg corresponding to the FBG reflected light by the Peak-Detection algorithm. When t_fbg is substituted into $\lambda = f(t)$, we can get the wavelength $\lambda\_FBG = f(t\_fbg)$. The FBG wavelength demodulation is completed.

3. Data Processing based on LabVIEW

First, we create a Labview program to read the experimental data containing both the original time domain signals of F-P transmission spectrum and FBG reflected spectrum. The experimental data is given by a text. This Labview program realizes the function of reading the experimental data by calling the different columns of a data text. When there are a lot of columns necessary to call, we can call any column only by rewriting the column index. The Labview program scheme of reading the experimental data is shown in Figure 5.

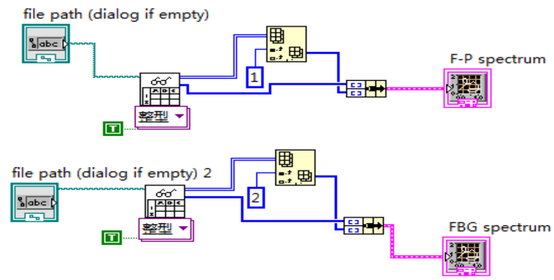

Figure 5. The Reading Data Program based on LabVIEW

In addition, the front interface of Labview program shows the original time domain waveforms of F-P transmission spectrum and FBG reflected spectrum respectively. It is shown in Figure 6. The experimental data waiting for being processed is directly perceived through the senses, which helps us confirm the range of some parameters involved in the demodulation algorithm.

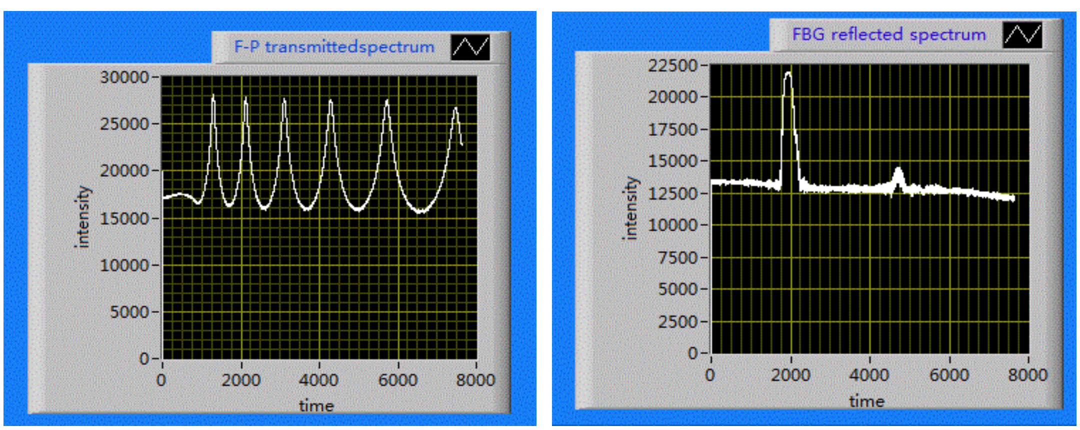

Figure 6. The Waveform Display on the Front Interface of LabView Program

Then, we compile the demodulation algorithm introduced in the principle into DLL files by the C programming language under the VC + +6.0. The DLL files contain the total demodulation idea, including the Peak-Detection algorithm on the two time domain signals of F-P transmission spectrum and FBG reflected spectrum, the binomial fitting algorithm and the FBG wavelength calculation. In the Peak-Detection algorithm, the Gaussian fitting is adopted in consideration of the fact that the peak spectrum in 3dB bandwidth is coincident to the Gaussian curve best at present. Because the wavelengths and the scanning time points only have a approximate linear relationship, here we choose the binomial fitting algorithm to fit this array to decrease the fitting error. The DLL files are called through a dynamic link library of Labview to establish a data processing program realizing the function of demodulation algorithm. By combining the reading and processing program, we get a data processing program shown in Figure 7.

On account of all the data processing algorithms being integrated in the dynamic link library, the whole program scheme can be divided into the three modules of reading the data, processing the data and displaying the result distinctly.

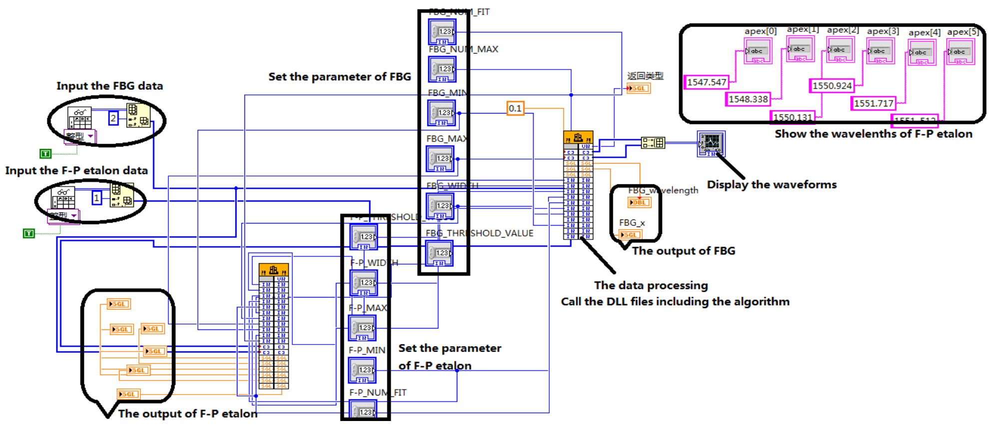

Figure 7. The Data Processing Block Diagram based on LabVIEW

Meanwhile, the front program interface shown in Figure 8 is set up. The interface displays the waveforms of F-P transmission spectrum and FBG reflected spectrum. According to the waveforms we can input the reasonable parameter on the left in the interface. When the appropriate parameters are set, the time points obtained by the Peak-Detection algorithm corresponding to each peak of the F-P etalon transmission spectrum and the FBG reflected spectrum are displayed above the waveform after running the program. The demodulation result-the center wavelength value of FBG reflected spectrum can reach over pm level. The resolution and stability meet the practical requirements currently.

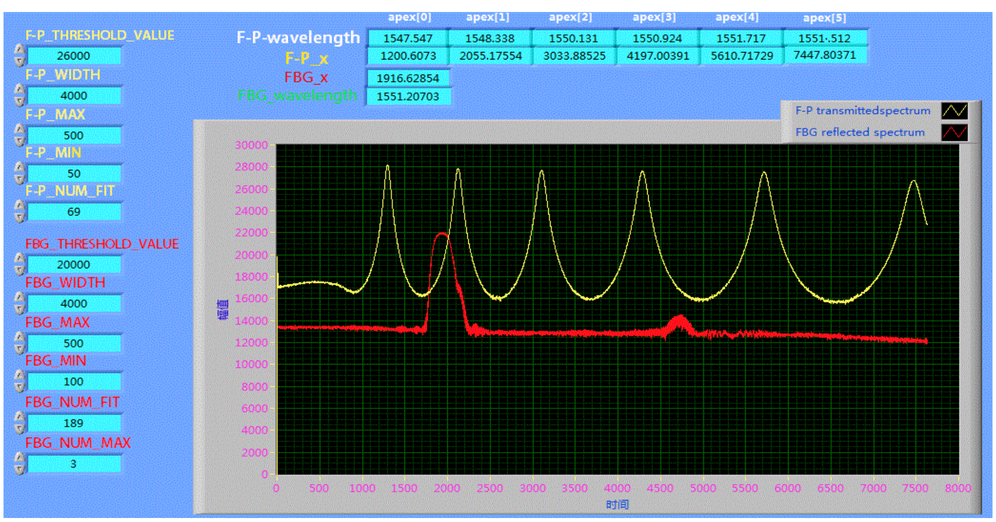

Figure 8. The Data Processing Control Interface

When there is multiple sensing FBG, we can call the DLL files repeatedly to do with the multiple columns data. For example, Figure 9 shows the condition that there are two FBG. But it wastes the resources and affects the working speed.

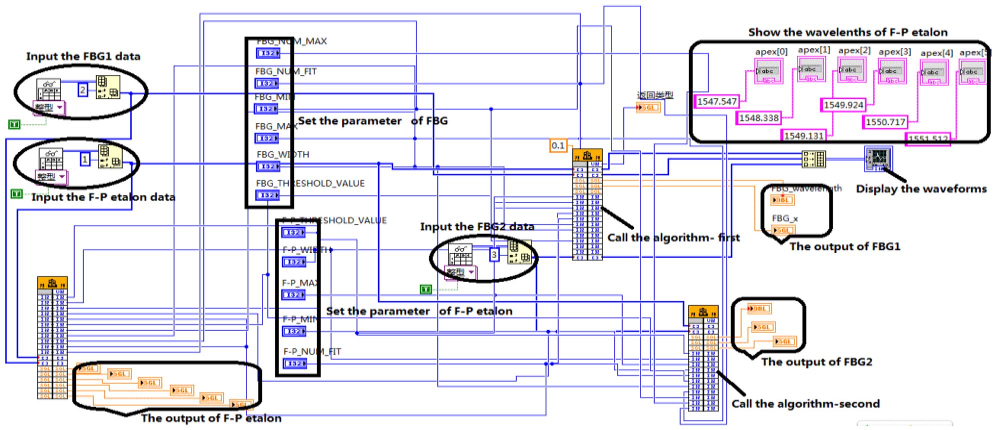

Figure 9. The Data Processing Program for two FBG

To resolve the problem above, we introduce a FBG index into the existing program, the relevant FBG data is called when the FBG index is changed. It is easy to operate and works fast. Only one FBG reflected spectrum displayed once avoids the waveform unclear. It is shown in Figure 10.

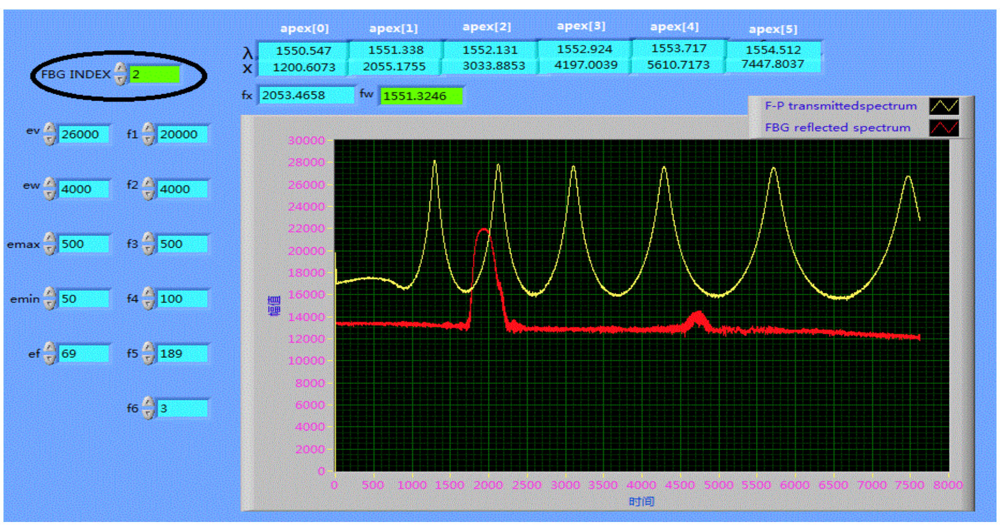

Figure 10. The Data Processing Program for Multiple FBG

The data processing program is concise and easy to amend， such as mentioned in Figure 9 and Figure 10. If the demodulation algorithm is improved, we amend the C program to create the new DLL files, the index of system can be improved only that the DLL files called through a dynamic link library of Labview is updated, the rest modules of program can keep invariant, hardware equipments of this demodulation system can also keep invariant. It is advantageous for optimizing and developing afterwards.

Acknowledgements

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