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Scientific Research

The Design of Fiber Bragg Grating Temperature Measurement System Based on Labview*

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ABSTRACT

The paper made a research on the fiber Bragg grating sensor demodulation system, which was based on virtual instrument labview and it developed a friendly upper monitor software. Based on the LM algorithm, the software realized rapid and accurate spectral data fitting, improving dynamic characteristics and measuring precision of the system. Depending on different fiber Bragg grating sensors, it can realize flexible calibration. It has the functions of collection, display and data storage, which can flexibly design alarm threshold according to the practical application. The fiber Bragg grating sensors can be identified by the software so that the distributed network, with large capacity optical fiber sensing, can be achieved.

Keywords: Optical Fiber Sensing; Labview; Temperature Measurement; Upper Monitor

1. Introduction

Fiber Bragg grating (FBG) sensors have attracted considerable research interests due to their encoded characters, anti-interference ability and capability of large—scale multiplexing [1]. As a new kind of optical passive components, FBG has the characteristics of high signal-to-noise, low loss and wide measuring range [2]. The resonance wavelength and amplitude are quite sensitive to the change of external parameters, such as the temperature [3], Lateral load [4], bending [5] and environment refractive index [6].

The upper monitor is a computer, which can send specific controlling command. By manipulating predefined command, it passes the command to the lower computer, which, according to the instruction, simply processes the gathered data and then through the USB interface sends it to PC, the host computer [7], to realize the functions of analysis showed and data storage on it. Nowadays, the fiber Bragg grating sensor demodulation platform can be completed by development tools, such as Visual C++, Delphi and Labview to realize data transmission, file writing and reading, interface showed, automatically saved and other functions and ultimately achieve multi-functional PC software.

Labview is developed by NI company sited in the United States. With a powerful data processing and programming function, it is a system combining a high performance hardware module and a flexible software to accomplish test and measurement tasks. Labview provides an integration module, with a large amount of data, including collection, analysis, display and storage [8], so that it greatly alleviates the complexity of programming. On the computer platform, users can design the test instrument system according to their own requirements. In order to do complex design, it becomes the main means for test and measurement system to do data acquisition, test, analysis and so on. We will complete the software design of the fiber Bragg grating sensor demodulation system by Labview, and achieves functions of data acquisition, display, saves and warning, etc.

2. The Idea of Fiber Bragg Grating Sensor Demodulation System

As shown in **Figure 1**, broadband light (1525 nm to 1565 nm) from ASE arrives in the series of grating through the optical circulator, from which the reflected light reaches demodulation module again through the optical circulator. The demodulation device of this system is based on vo-

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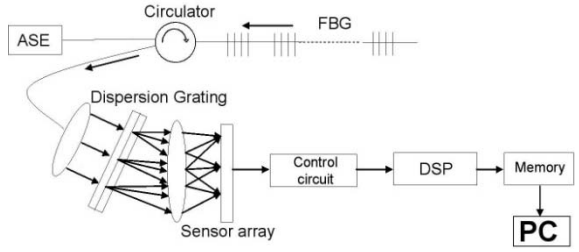

Figure 1. Schematic diagram of temperature demodulation system.

lume grating. Out from the optical circulator, the light through the optical fiber collimator parallel incident into the volume grating and transmission of the light from which projected on the line array of PIN after convex lens.

After the parallel light irradiate into the volume grating, the light with the same wavelengths will be emitted from the same direction and then the light of different wavelengths will focus on the different positions after convex lens. Based on the output signal of PIN line array tested, the input spectrum can be rebuilt and the Bragg wavelength of fiber grating can be gained so that the temperature or strain can be finally inverted. In order to achieve the temperature sensor data, the system adopts the optical fiber grating temperature sensor which is only sensitive to temperature.

After the direction of incident parallel light is determined, the line array pixel of the PIN and the wavelength has a one-to-one corresponding relationship. When temperature changes, the Bragg wavelength of the sensing grating will drift, leading to the change of the position of the maximum light power point incident to the line array PIN. Through the subsequent circuit processing, the position of the maximum power point can be obtained and then the changed Bragg wavelength.

By the Labview software, the VI program is written, demodulation module of gathering data can be read and processed to instantly display the corresponding relation between environment temperature and center wavelength.

3. Design of the PC Software Using Labview

This project adopting the optical fiber Bragg grating temperature demodulation software developed by Labview can realize the acquisition and processing of sensor data, real-time display the center wavelength and the corresponding temperature and set the sensor parameters and automatically save data.

The Software design includes the following parts: parameters setting, spectral fitting, temperature display, waveform display, data storage and temperature alarm.

3.1. Spectral Fitting-LM Algorithm

The PIN structure has a relatively higher sensitivity and internal gain, which make the demodulation module have a high signal noise ratio (SNR). But the PIN has a small number of pixels and the acquisition point of the light power is limited. The bigger spacing of adjacent pixel makes the received optical power not certainly the maximum intensity of the center wavelength location, which probably cause measurement error. We adopt LM algorithm of Gaussian to linear fitting by multiple sampling point near the peak and then get the highly accurate Gaussian spectrum.

The received data are taken from the sampling point to peak fitting. Given fitting function:

$$f(\nu)=\sum_{i=1}^{n} R_i \exp\left[-4\ln 2\left(\frac{\nu-\nu_{Bi}}{\Delta\nu_{Bi}}\right)^2\right]$$

Where n is the number of Bragg grating. ν is the wavelength. ν_{Bi} is the initial value of the i_{th} center wavelength. $\Delta\nu_{Bi}$ is the initial FWHM (full width half maximum) of grating spectrum.

$$y = f(v; x_1, x_2, \ldots, x_n) = \sum_{j=1}^{k} f_j(v; x_{j1}, x_{j2}, x_{j3})$$

The purpose of spectrum line fitting is to obtain the coefficient by minimizing

$$\varphi(x_1, x_2, \cdots x_n) = \sum_{i=1}^{m} \left[f(v_i; x_1, x_2, \cdots x_n) - y_i \right]^2 ,$$

where, y_i is the measured spectrum data, m is the number of measured data.

3.2. Data Collection, Processing and Display

The typical external interface includes the call to DLL, COM and ActiveX. The data interface between hardware and software in the project needs the communication with the modulation module through dynamic library file WIN32Shared.DLL to realize the calls to objective function. The dynamic link library includes the library files of multiple functions or resources. Functions and data are stored in the DLL for export use, in which the executable files contain only the link library files referring to functions and the description information of those functions in documents. The call can be achieved to DLL through a call library functions (CLF) node. But before the call, we need to guide the dynamic link library functions, as shown in **Figure 2**. The return value of a function can be empty, integer or floating point pointer. The function's parameters, data type, transfer sequence need setting and procedure and storage location need calling to complete the calls to the objective function.

The main objective functions in WIN32Shared. DLL is as follows:

BOOL DLL_Open_Device(int SerialType);

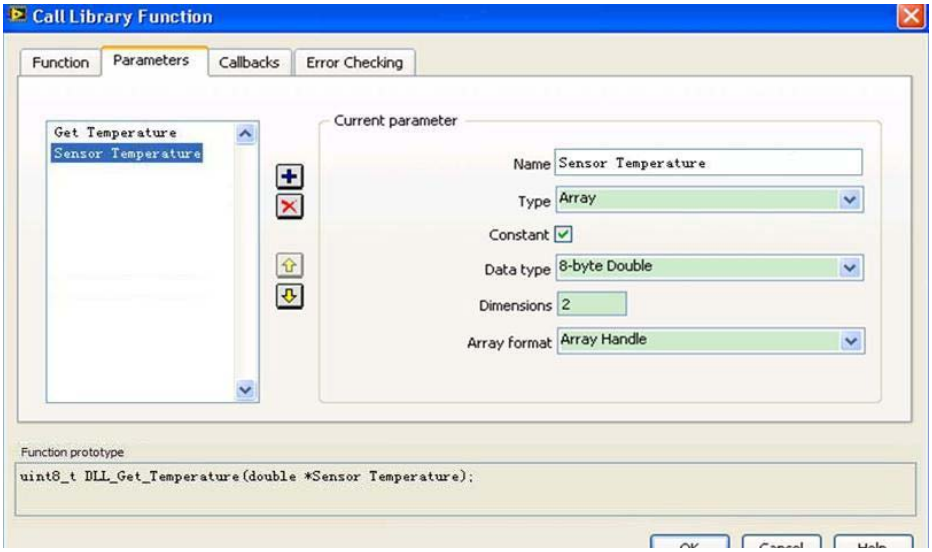

Figure 2. The configuration interface of Library function.

Function: Access the module through the USB interface.

BOOL DLL_Get_Wavelength (double Case Temperature, double* Wavelength);

Function: Realize temperature display function through access module by the USB interface and obtain the wavelength value from the corresponding pixels.

BOOL DLL_Get_Peaks (DWORD SpectrumIndex, WORD* PeakCount, Double* pWavelength, double* pPower);

Function: Get the index spectrum, the peak number of wavelengths and power values from each channel through access module by the USB interface.

The design process of the system is shown in **Figure 3**. The basic parameters of software running are configured by starting the interface. If the initialization succeeds, the interface will shut down automatically and open the main interface at the same time. Then we choose the light channel and the 1 × 4 light switch, set the sensor model, integration time, noise threshold and load the data of calibration wavelengths corresponding to the pixels. Data collection is completed in the hardware system itself, which will send the instruction of getting spectra data to module by calling the library function node. When receiving the response signal, the module began to obtain spectral data. Due to the limit of line array pixel of the PIN, the module will output 512 16-bit electrical signal data after the photoelectric conversion completed. Because of it, the spectrum data we receive is only 512 groups each time. The main program calls the target functions from link library WIN32Shared.DLL, reads the power value, channel wavelength values and optical signal-to-noise ratio from each pixel and gets the number of peaks and the corresponding wavelengths by the Gaussian function.

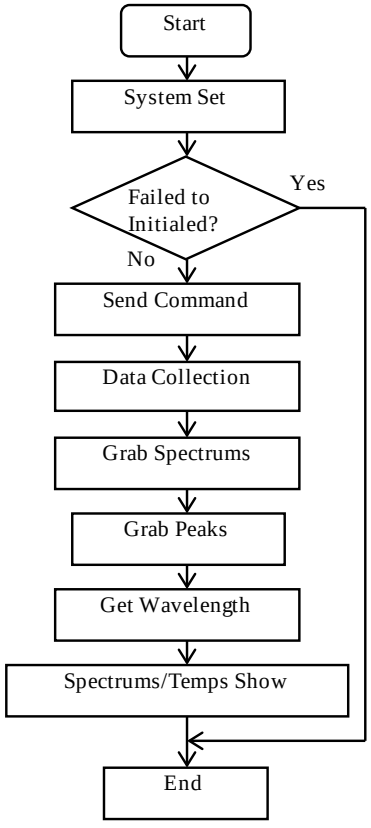

Figure 3. The design progress of the system.

As shown in **Figure 4**, owing to each pixel corresponding to one wavelength values, we initialize the 512 pixels and get the wavelength values of each point by loading the wavelength getting function. Then the pixel-wavelength conversion is completed and the visual display of power-wavelength is generated by creating the XY graph.

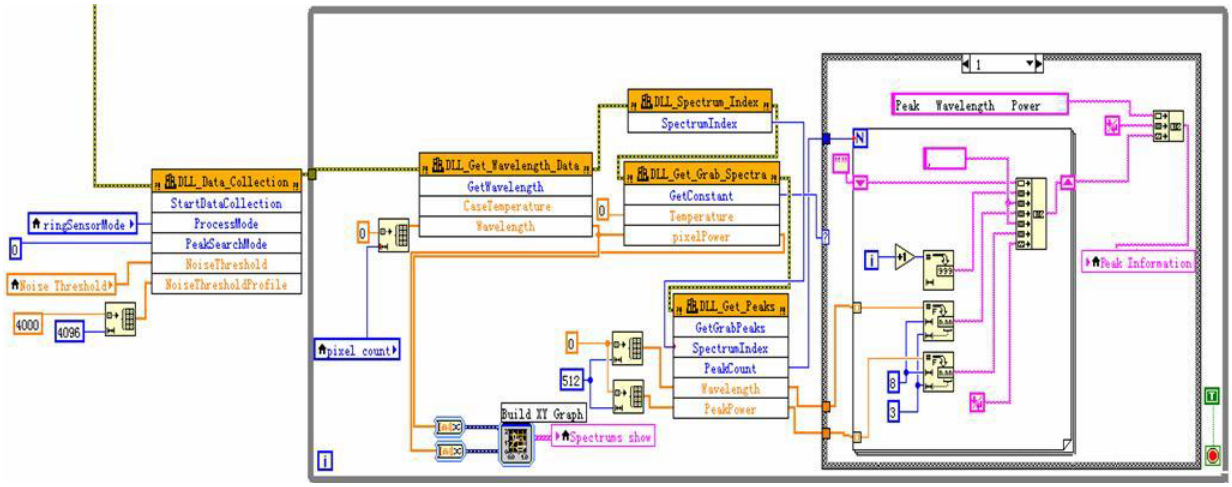

Figure 4. Get the data and peak program.

3.3. The Temperature Calibration of the Sensor

Through the calibration experiment of temperature in the temperature control box, the grating characteristic curve is obtained by the fitting of wavelength and temperature data. And then the temperature characteristic equation is written in the program. As shown in **Figure 5**, in the configuration panel interface, we set temperature calibration parameters and load the coefficient of temperature, wavelength of calibration and temperature of calibration. After processing the FBG temperature characteristic equation, the center wavelength can be converted to the environmental temperature. After the fiber grating is replaced, temperature calibration parameters can be reloaded by the same means, which can realize flexible calibration processing on temperature.

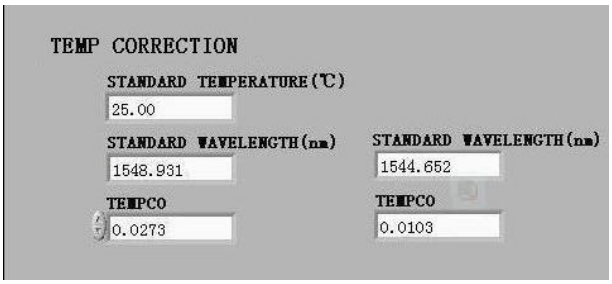

Figure 5. The temperature calibration module.

3.4. Sensor Identification and Threshold Value Warning

Because the grating sensor has a certain bandwidth within the scope of effective temperature, the wavelength characteristics of the adjacent sensors need to have an interval at least 2 nm. After reading the peak wavelength, the application can automatically choose the range of center wavelength belonging to, and then select the corresponding temperature characteristic equation to transform the wavelength data into temperature value. When getting multiple grating series together, the program can realize the demodulation of temperature in the same interface but from different positions and gratings through the selection function of distribution wavelength value.

As shown in **Figure 6**, the system of the program is equipped with an alarm function. The temperature alarm function displays being normal under the normal condition. When the measured temperature exceeds the set threshold, the warning lights will automatically turn red and the buzzer alarm.

Figure 6. The module of alarm function.

4. Temperature Demodulation System's Implementation and Verification

Building an experimental platform, two Optical fiber Bragg grating temperature sensors are chosen in series to the light path, the center wavelength of which are 1548.931 nm and 1544.652 nm. The software is used to complete demodulation processing of sensing data.

As shown in **Figure 7**, the spectrum diagram clearly shows the center wavelengths of two different gratings. The number of the peak, the center wavelengths and optical power values in the form of a chart under the spectrum show that the center wavelengths of the two gratings have occurred a certain drift. The temperatures of the two corresponding gratings can be directly read out in the right temperature display column, in which the above corresponds to 1548.931 nm grating and the below cor-

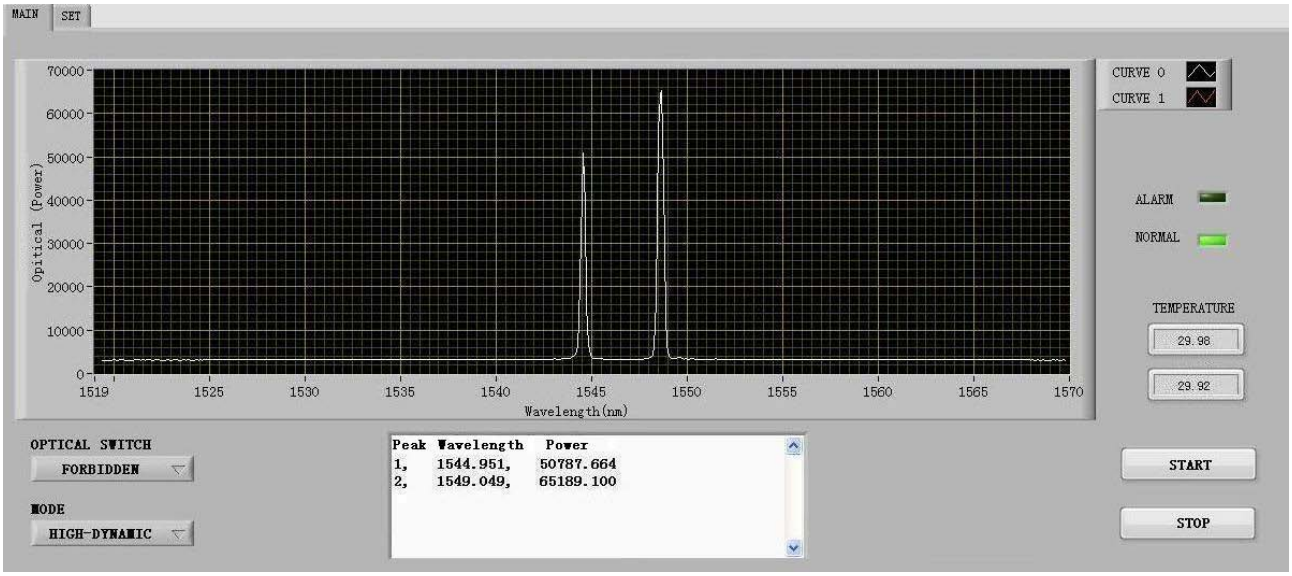

Figure 7. The main interface of temperature demodulation.

responds to 1544.652 nm grating. The alarm is set at a temperature of 30˚C and the equipment displays being normal.

5. Conclusion

In reference to a large number of application examples, we complete the research and design of sensor demodulation system by utilizing the development platform of the visual instrument Labview. The LM algorithm is loaded in Labview, which completes the spectral data accurate fitting and peak processing and in the meanwhile improves the measurement precision of the system. Through the Internet communication with hardware devices, the program achieves functions of data acquisition, display and saves. According to practical application, the alarm threshold value system can be flexibly designed. By choosing different types of gratings applied to the system, the flexible processing of temperature calibration is completed. The identification function of the fiber Bragg grating sensor achieves the temperature demodulation of different gratings at the same time. The experimental results show that the validity and accuracy of demodulation system are verified, the design and implementation of which lay a solid foundation for the subsequent upgrade, development and engineering practice.

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