A technique of Data Acquisition and Processing in Fiber Grating Sensing System

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Abstract. The multi-channel intelligent optical sensing technology is used in the gyroscope, and the optical fiber sensing technology is optimized through the fiber grating sensing system for data acquisition and processing. The MAX120 chip is used to realize the A/D conversion of the initial spectral signal, the hardware system connects the optical fiber sensor to realize the organic integration between the circuit components. And the preprocessing process of the intelligent information signal is realized through the two steps of data transformation filtering and improving the spectral resolution of the signal. It can solve the problems of slow acquisition speed and low signal-to-noise ratio in the traditional spectral acquisition system. After system testing, it is concluded that compared with the traditional spectral acquisition system, the time of primary spectral acquisition in the intelligent information signal spectral acquisition system based on optical fiber sensing is saved by 1.47s, and the signal-to-noise ratio is improved by 14dB.

1. Introduction
Nowadays, spectrum acquisition technology has become one of the important technologies for exploring the generation of spectrum and the interaction between light and matter, and it is involved in many industries and fields. In recent years, the upgrade and optimization of photodetector elements have not only made the size of the device smaller, but also continued to improve its performance, and formed a corresponding system and system[1].

However, in the traditional information spectrum collection system, because the information spectrum data processing module is not equipped, the collected data has a large noise, and the transmission and collection speed of the spectrum sensor equipment used in the traditional system is slow, which affects the system's performance. The collection efficiency is reduced.

In order to solve the above-mentioned problems, this paper proposes an intelligent information signal spectrum acquisition system based on optical fiber sensing. The design of this system needs to solve many problems in the traditional acquisition system and design the system from multiple aspects. First of all, in terms of hardware, in addition to continuing to use the relevant hue and imaging systems, it is also necessary to use optical fiber sensing equipment to replace traditional sensing equipment, and to replace the circuit of the entire system with an optical fiber circuit[2]. In terms of software, a spectral signal processing program needs to be added to achieve the function of filtering signals, thereby enhancing the credibility of the collected spectra.
2. Hardware system design
The hardware system of intelligent information signal spectrum acquisition mainly includes light source lighting module, collimator module, dispersion and imaging module, and data processing hardware support module[3].

The light source illumination system is set as a laser, and the collimator and dispersion device are optical fiber sensors. In addition, a specific improvement design should be made for the A/D conversion chip device of the hardware system and the circuit of the entire system.

2.1. Optical fiber circuit design
The optical fiber circuit mainly includes A/D conversion circuit, buffer circuit and acquisition main board circuit. Determine the A/D reference voltage according to the input range of the suitable A/D conversion chip. Since the output voltage range of the collected results is $[5.37, 7.0]$, the reference voltage for A/D conversion is $0$–$3.6V$ to ensure that it meets the requirements of the input signal[4]. The pin setting of the A/D fiber optic circuit is shown in Figure 1.

![Figure 1 A/D optical fiber circuit pin diagram](image)

2.2. Optical signal transmitting and receiving device
In this hardware system, a laser is selected as the light source emitting device[5]. In the choice of laser, it is necessary to ensure that the laser has a good spatial mode and spatial directivity, along with a stable power output, to increase the signal-to-noise ratio of the signal from the root. In addition to the laser, the collimating device composed of the incident slit and the collimating objective lens, as well as the dispersive spectroscopic device that realizes the decomposition of the incident composite light into the spectrum, are all optical signal emitting devices [6].

2.3. A/D conversion equipment
In the signal spectrum acquisition system, the chip of the A/D conversion device needs to be selected. The following conditions need to be considered when selecting: to ensure the accuracy and precision of the conversion; to realize the adjustment of the conversion speed according to the signal change speed of the visible light emitted by the laser; to ensure the conversion digits of the converter [7]. The number of conversion bits of the A/D chip directly affects the absorbance of the optical fiber sensor.
Assuming that the slope length of the object to be measured is 340nm, the content of stray light is 1%, and the 8-bit A/D conversion chip is used, the absorbance is:

$$A = \lg \frac{1}{T} \cdot 2^8$$  \hspace{1cm} (1)

The denominator in Formula 1 refers to the quantized digital quantity. If the conversion digits of the A/D conversion chip are 12 digits, the absorbance is:

$$A = \lg \frac{1}{T} \cdot 2^{12}$$  \hspace{1cm} (2)

It can be seen from the above two calculation formulas that under the same stray light content condition, the absorbance of different conversion chips is different. In order to get better acquisition results, the 12-bit A/D conversion chip MAX120 is used in this acquisition system[8].

MAX120 is composed of four-season broadband input sampling and holding circuit pipeline structure. Each assembly line structure unit packs one, or even more than one, low-resolution blinking A/D conversion chip, and the terminal interface of the converter is connected to the voltage amplifier.

3. Software system design

The structure of the intelligent information signal spectrum acquisition software system is shown in Figure 2:

![Figure 2](image)

Figure 2 The structure diagram of the signal spectrum acquisition software system

3.1. Analog signal acquisition

Single continuous acquisition of signal spectrum can ensure real-time acquisition results. The multi-wavelength continuous scanner is carried out in a cyclic manner, which can ensure the accuracy of the value of the optical fiber wavelength range injected by the optical fiber sensor, and collect the signal value of the spectrum in real time.
3.2. Spectral signal A/D conversion
Assuming that the signal data collected during the analog signal sampling process is divided into three data signal sets, the collected analog signal is converted into a digital signal through the spectral signal A/D conversion process as shown in Figure 3.

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Figure 3 Flow chart of analog signal A/D conversion
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3.3. Intelligent information signal preprocessing
Preprocessing is mainly divided into 4 steps, among which the purpose of intelligent data transformation filtering is to convert the initial signal into the form of a spectral signal and filter the noise elements in it. On this basis, the resolution is improved, and the peak location result of the spectral image is obtained. The Fourier transform method is used to transform the time-domain continuous signal obtained by the A/D conversion. Suppose the digital signal obtained by A/D conversion is represented by $x(n)$, where $n$ represents the number of times the analog signal is sampled, and the inverse Fourier transform is performed by formula 3.

$$X(k) = \sum_{n=0}^{N-1} x(n) W_N^{-nk}, k = 0,1,\ldots,n-1$$  \hspace{1cm} (3)$$

$W_N$ is the rotation transformation factor. When standard conversion is performed on all $x(n)$, for each element of $X(k)$, it is necessary to perform $N$ complex multiplication and addition operations. The calculation formula is as follows:
\[ X(n) = X(n) \exp \left( -j \frac{2\pi kn}{N} \right) \]  

(4)

By controlling the noise filter coefficient, the noise filter coefficient in the high-frequency unit is reduced, so that the noise becomes smooth. Perform inverse transformation on the noise suppression coefficient after noise suppression to obtain the filtered and smoothed signal. The collected and processed spectral image information is stored in the PC peripheral memory through data transmission, and displayed on the PC screen according to the collection requirements.

The detection of the system uses a laser as the incident light source, adjusts the incident light source to a parallel light source, and sets up the focal length of the laser to be 50±5mm. According to the hardware requirements of the system, install the corresponding hardware devices and debug each hardware device. The operating system for the system test platform is Windows 7, and the CPU processor is Intel AMD AM2 Athlon 64 X2.

4. System testing and analysis

In the process of system function testing, a traditional acquisition system is set up as a comparison system for functional testing. The two collection systems collect the same set of visible light beam information, and the light beams to be collected contain 5 different pieces of information, which are numbered according to the order of incidence. The collection time, intensity and environment used in the collection process of the system are the same. Separately count the number of signal spectrum acquisitions of the two systems in the same time, and analyze the spectrum collected by the system through the calculation formula of speed and signal-to-noise ratio, and obtain a functional test about the acquisition speed and the signal-to-noise ratio of the acquisition result. The results are shown in Table 1.

| number of visible beam | Traditional signal spectrum acquisition system | Intelligent signal spectrum acquisition system based on optical fiber sensor |
|------------------------|-------------------------------------------------|------------------------------------------------------------------------|
|                        | Acquisition time | Signal to noise ratio | Acquisition time | Signal to noise ratio |
| 1                      | 3.78s            | 60dB                  | 2.44s            | 87dB                  |
| 2                      | 5.41s            | 78dB                  | 3.33s            | 79dB                  |
| 3                      | 4.39s            | 62dB                  | 2.98s            | 82dB                  |
| 4                      | 6.28s            | 75dB                  | 5.53s            | 90dB                  |
| 5                      | 3.71s            | 81dB                  | 1.94s            | 88dB                  |

It can be seen from the test data in the table that the average acquisition time of the traditional acquisition system is 4.714 s/piece, and the average signal-to-noise ratio is 71.2 dB. The acquisition time and average signal-to-noise ratio of the optical fiber sensing-based intelligent information signal spectrum acquisition system are 3.244 s/piece and 85.2 respectively. In contrast, the acquisition time of the intelligent information signal spectrum acquisition system has been saved by 1.47 s/piece, and the signal-to-noise ratio has been increased by 14 dB. Therefore, the designed signal spectrum acquisition system has faster acquisition speed and higher quality of the acquired signal spectrum.

5. Conclusions

Practice has proved that the intelligent adjustment and processing of the signal spectrum improves the signal-to-noise ratio of the spectrum signal, avoids the process of manual adjustment by personnel, and realizes the intelligentization of the system. Through the application of the signal spectrum acquisition system, the acquired spectrum image is smooth and undistorted, which has high application value.

References

[1] Liu G, Hu J, Wang Z. (2018) Weak signal processing technology of hyperspectral lidar echo based on wavelet transform. Semiconductor Optoelectronics, 39(5): 144–149.
[2] Li S, Wang Y, Cui H. (2017) Laser confocal Raman spectroscopy imaging technology and system with anti-drift characteristics. Spectroscopy and Spectral Analysis, 37(10):3249-3254.

[3] Liu Y, Wang W. (2018) Design of Universal Laser Absorption Spectroscopy System Based on LabVIEW Platform. Shanxi Chemical Industry, 174(2): 22-25.

[4] Yang L, Zheng J. (2017) The influence of signal spectral width characteristics on SBS threshold of single-frequency fiber amplifier. Chinese Journal of Lasers, 31(9): 63-68.

[5] Ma L. (2017) Design of Laser Gyro Data Acquisition Circuit Based on TMS320C6713. Electronic Design Engineering, 25(4): 63-65.

[6] Wang S, Xia J. (2018) The design of the front optical system of the long-range laser Raman spectroscopy detection system. Infrared and Laser Engineering, 47(4): 207-214.

[7] Li A, Shao Q. (2017) Overview of a new portable laser-induced breakdown spectroscopy system. Chinese Optics, 10(4): 426-437.

[8] Li K, Xin J. (2018) Sensing demodulation system using ultra-short FBG spectral linear region. Optics and Precision Engineering, 26(1): 31-37.