Optic fiber pulse-diagnosis sensor of traditional Chinese medicine

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ABSTRACT

The wrist-pulse is a kind of signals, from which a lot of physiological and pathological status of patients are deduced according to traditional Chinese medicine theories. This paper designs a new optic fiber wrist-pulse sensor that based on a group of FBGs. Sensitivity of the optic fiber wrist-pulse measurement system reaches 0.05% FS and the range reaches 50kPa. Frequency response is from 0 Hz to 5 kHz. A group of typical pulse signal is given out in the paper to compare different status of patient. It will improve quantification of pulse diagnosis greatly.

Keywords: Optic fiber sensor; wrist-pulse waveform; medicine measurement

1. INTRODUCTION

Pathologic changes of a person's body condition are reflected in the wrist-pulse pictures. The wrist-pulse shape, amplitude, and rhythm are also altered in correspondence with the hemodynamic characteristics of blood flow. From the medicine view, pulse diagnosis is to perceive the variations of blood pressure of wrist of a patient, and it is very important in clinical procedures, providing diagnostic measurements related to the causes of disease, the locations of disease, the nature of disease, and predictions of a cure [1, 2].

In history, Chinese physicians clearly appreciated the significance of the wrist-pulse and association of changes in the wrist-pulses with diseases, but they did not progress beyond the stage of manual palpations, thereby remaining largely uninfluenced by quantitative measurements. Wrist-pulse assessment is a matter of technical skill and subjective experience. The intuitional accuracy depends upon the individual's persistent practice and quality of sensitive awareness. Different Chinese physicians might not always give identical wrist-pulse conclusion in their medical literatures. Solid quantified description of Chinese pulse diagnosis would pave a way in its modernizing advancements [3]. There are some previous works have been down by many researchers in recent decades [4-8]. Most of previous works are based on electronic sensors including piezoresistive Si-sensor, piezoelectric sensor or doppler blood flow meter. In this paper, we proposed a new optic fiber sensor that can measure wrist-pulse waveform in a large frequency rang and high sensitivity.

2. OPTIC FIBER PULSE-DIAGNOSIS SENSOR

The basic principle of FBG's is to measure the shift of reflected Bragg wavelength (λ_b), which is related to the effective refraction index (n_{eff}) and the periodicity (Λ) of the index variation of the grating area in fiber core. The Bragg wavelength is given by the expression:

$$\lambda_{\mathrm{b}} = 2\mathrm{n}_{\mathrm{eff}}\Lambda \tag{1}$$

Any perturbation that can change effective index (n_{eff}) and periodicity (Λ) will result in a shift in Bragg wavelength. Strain is such a perturbation, on which wrist-pulse monitoring has focused.

Differentiating (1), we obtain
$$\mathrm{d}\lambda_{\mathrm{b}} = 2\Lambda dn_{\mathrm{eff}} + 2\mathrm{n}_{\mathrm{eff}}\mathrm{d}\Lambda \tag{2}$$

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(2) divided by (1) , therefore

$$\frac{d\lambda_b}{\lambda_b} = \frac{dn_{eff}}{n_{eff}} + \frac{d\Lambda}{\Lambda} \quad (3)$$

where dΛ/Λis strain (ε). The neff changes induced by strain (ε) can be given as

$$\frac{dn_{eff}}{n_{eff}} = -\frac{n_{eff}^{2}}{2}[p_{12} - \upsilon(p_{11} + p_{12})]\varepsilon \quad (4)$$

Where p_{11} and p_{12} are Pockel's coefficients of strain-optical tensor, and υ is materials Poisson's ratio.

Giving $P = [p_{12} - \upsilon(p_{11} + p_{12})]n_{eff}^{2}/2$, thus we get

$$\frac{d\lambda_b}{\lambda_b} = (1 - P)\varepsilon = K_{\varepsilon}\varepsilon \quad (5)$$

where K_ε is strain sensitivity. (5) is the equation between FBG wavelength shift and strain without considering the temperature change. If the optical fiber core is silicon dioxide, the corresponding *P* is about 0.22 and the strain sensitivity coefficient is about 1.2 pm/ με for the FBG whose wavelength is 1550 nm or so [9].

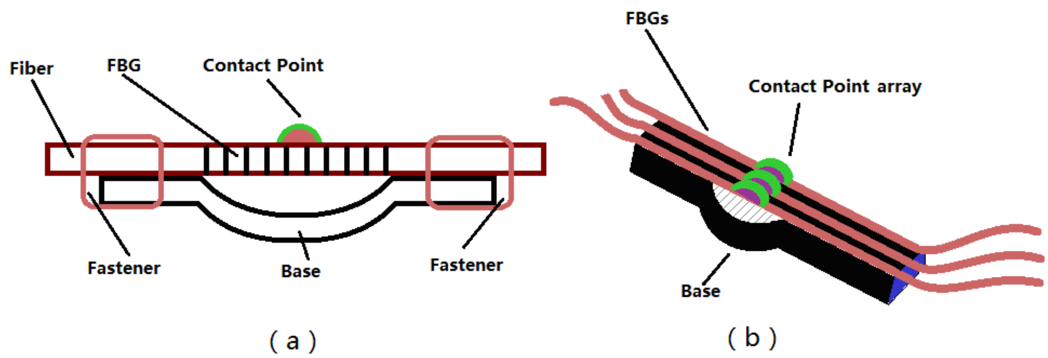


Fig.1 Structure of the optic fiber pulse senor

As Fig.1 shows, the optic fiber pulse-diagnosis sensor is composed with base, fastener, contact point, fiber and fiber Bragg grating (FBG). The sensor fastens the FBG on the base, which is bended in the center to provide a space for transverse stress of the FBG. Contact point conduct the pulse pressure to the FBG and makes it bended. The center wavelength of the FBG depends on strain created by contact point pressure, so that the pulse's physics fluctuating can be embodied in FBG's wavelength changing.

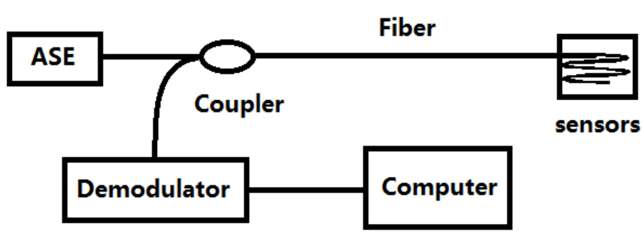


Fig.2 Diagram of the optic fiber pulse sensor system

In practical application, a big problem is how to find measuring position of the pulse accurately considering vessel is misty and slender. Thereby, our sensor uses a group of FBGs to compose an array. The clearest waveform of the array can be considered as the pulse signal.

3. EXPERIMENTS AND RESULTS

Fiber wrist pulse-diagnosis meter is shown in Fig.3. It is included fiber wrist pulse sensor, jig and interrogator. FBG sensors' spectrum are monitoring by a interrogation monitors that made by Ibsen Photonics. Jig is designed to make pulse-taking convenient.

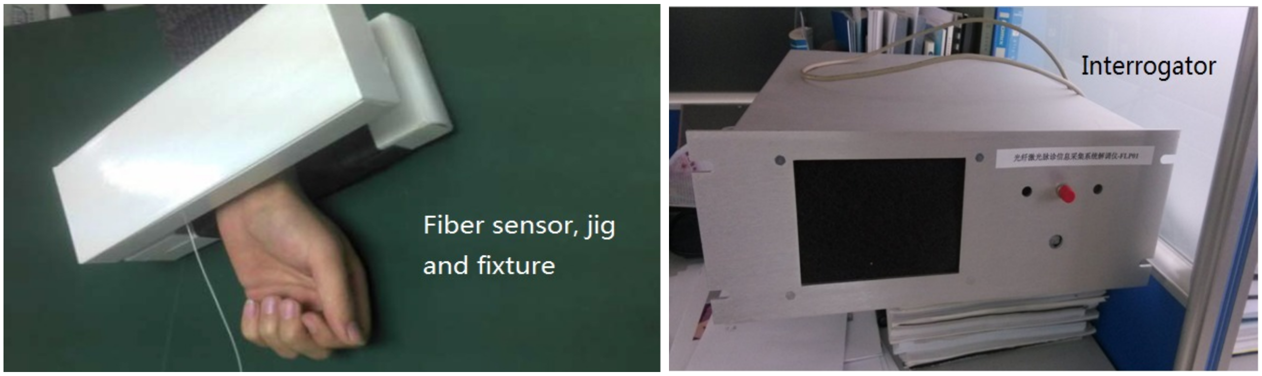
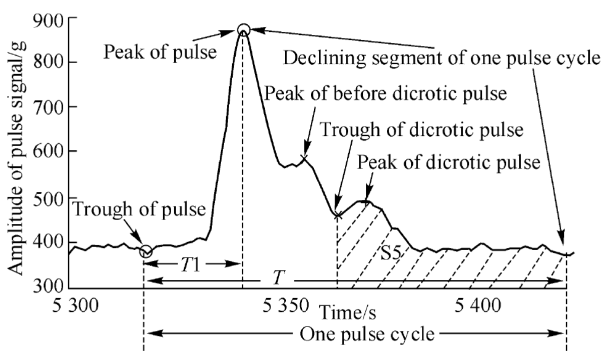


Fig.3 The major components of the Optic Fiber Pulse Diagnosis meter.

Time domain analysis looks at the arterial pressure waveform with respect to time, and a time domain graph shows how the arterial pressure waveform changes over time. It is widely used in the quantification of pulse condition [10].



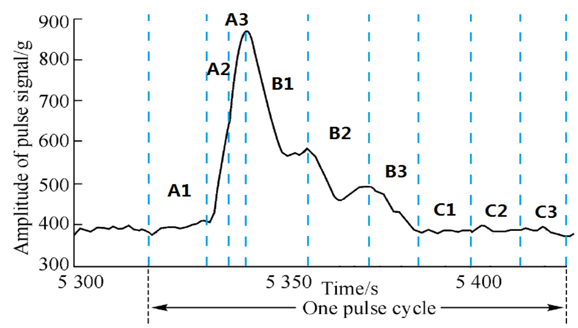


Fig.4 Illustration of the typical pulse waveform [11] Fig.5 Illustration of piecewise waveform

The most important trough of pulse time domain features of the basic pulse wave unit [11] are shown in Fig.4. We demarcate pulse waveform into 6 parts along axial in order to analysis signals in detail, as Fig.5 shows.

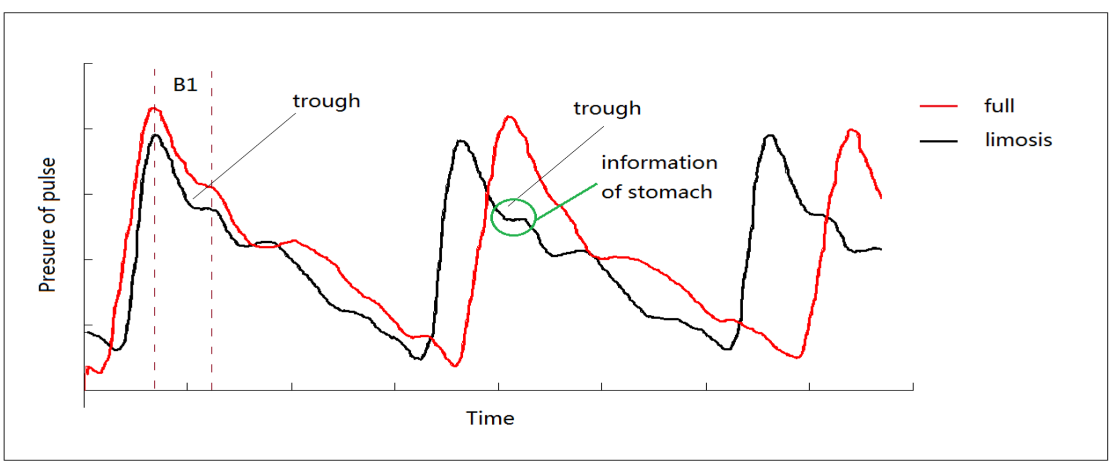


Fig.6 Pulse waveform taking by optic fiber sensor

By our previously research, different apparatus status are exhibited on different segment and pulse taking depth. Some pulse waveforms, which aimed at finding out stomach information, are shown in Fig.6. When the pulse taking depth (pressure) is fixed to about several hundreds Pa, section B1 of the waveform shows out stomach information. In another words, some information of the stomach will be highlighted in this trough area. For example, some kind of gastritis will be manifested as high-frequency wave stacking on normal waveform in the circled area of fig.6. The rest can be done in the same manner to other diseases.

4. CONCLUSION

The wrist-pulse waveform signal of patient contains important information about their disease condition. In this paper, we establish an optic fiber pulse measuring system to monitor patient's wrist-pulse signals. First, principle of optic fiber pulse sensor that based FBGs is introduced. Secondly, structure of the sensor and measuring system are described in detail. Experiment results show that optic fiber pulse measuring system can take wrist-pulse waveform accurately. In addition, some waveforms of wrist-pulse are given out especially focus on stomach information. In future, we will do more clinical trial to find out more information by our optic fiber pulse sensor, since we have already found some liver and lung cancer characteristic signals located in A2 section and B1 section of the wrist-pulse waveform by manual pulse diagnosis. Those works will make great contribution to characterization and modernization of Traditional Chinese Medicine.

Acknowledgements

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