中国光学（中英文） Chinese Optics 核心期刊

Vibration sensor based on stretchable optical fiber and interferometric measurement

WU Jia-jun, XIE Kang, CAO Lei, CAO Xuan, LI Zhen-jia, ZHAO Guo-shuai, HE Jia-cheng, TU Guo-jie

Citation:
WU Jia-jun, XIE Kang, CAO Lei, CAO Xuan, LI Zhen-jia, ZHAO Guo-shuai, HE Jia-cheng, TU Guo-jie. Vibration sensor based on stretchable optical fiber and interferometric measurement[J]. *Chinese Optics*, 2025, 18(5): 1200-1208. doi: 10.37188/CO.EN-2025-0010
吴加俊, 谢康, 曹磊, 曹璇, 李振佳, 赵国帅, 何佳程, 涂郭结. 基于可拉伸光纤和干涉测量的振动传感器[J]. 中国光学, 2025, 18(5): 1200-1208. doi: 10.37188/CO.EN-2025-0010

View online: https://doi.org/10.37188/CO.EN-2025-0010

Articles you may be interested in

A Hilbert-Huang transform method for vibration localization based on a dual Mach-Zehnder distributed optical fiber sensor
基于希尔伯特-黄变换的双马赫-曾德分布式光纤传感振动定位方法
Chinese Optics. 2021, 14(6): 1410 https://doi.org/10.37188/CO.2021-0065

Research progress of optical fiber Fabry-Perot interferometer high temperature sensors
光纤法布里-珀罗干涉仪高温传感器研究进展
Chinese Optics. 2022, 15(4): 609 https://doi.org/10.37188/CO.2021-0219

Design of optical wedge demodulation system for fiber Fabry-Perot sensor
光纤法珀传感器光楔式解调系统设计
Chinese Optics. 2021, 14(5): 1259 https://doi.org/10.37188/CO.2020-0204

Interrogation technology for quasi-distributed optical fiber sensing systems based on microwave photonics
基于微波光子学的准分布式光纤传感解调技术
Chinese Optics. 2021, 14(2): 245 https://doi.org/10.37188/CO.2020-0121

Fiber bragg grating temperature and pressure sensor for oil and gas well
油气井下光纤光栅温度压力传感器
Chinese Optics. 2021, 14(5): 1224 https://doi.org/10.37188/CO.2021-0008

A novel methane and hydrogen sensor with surface plasmon resonance-based photonic quasi-crystal fiber
基于表面等离子体共振的光子准晶体光纤甲烷氢气传感器
Chinese Optics. 2023, 16(1): 174 https://doi.org/10.37188/CO.EN.2022-0006

文章编号 2097-1842(2025)05-1200-09

Vibration sensor based on stretchable optical fiber and interferometric measurement

WU Jia-jun, XIE Kang, CAO Lei, CAO Xuan, LI Zhen-jia, ZHAO Guo-shuai, HE Jia-cheng, TU Guo-jie*
(*School of Physics and Optoelectronic Engineering*, *Information Materials and Intelligent Sensing Laboratory of Anhui Province*, *Key Laboratory of Opto-Electronic Information Acquisition and Manipulation*, *Ministry of Education*, *Anhui University*, *Hefei* 230601, *China*)
* *Corresponding author*, *E-mail*: 15041@*ahu.edu.cn*

Abstract: Soft polymer optical fiber (SPOF) has shown great potential in optical-based wearable and implantable biosensors due to its excellent mechanical properties and optical guiding characteristics. However, the multimodality characteristics of SPOF limit their integration with traditional fiber optic sensors. This article introduces for the first time a flexible fiber optic vibration sensor based on laser interference technology, which can be applied to vibration measurement under high stretch conditions. This sensor utilizes elastic optical fibers made of polydimethylsiloxane (PDMS) as sensing elements, combined with phase generating carrier technology, to achieve vibration measurement at 50−260 Hz within the stretch range of 0−42%.
Key words: stretchable optical fiber sensing; fiber optic vibration sensor; phase generated carrier

基于可拉伸光纤和干涉测量的振动传感器

吴加俊,谢 康,曹 磊,曹 璇,李振佳,赵国帅,何佳程,涂郭结*
(安徽大学 物理与光电工程学院,信息材料与智能感知安徽省实验室,光电信息获取与控制教育部重点实验室,安徽 合肥 230601)

摘要:软聚合物光纤(SPOF)因其优异的机械性能和光导特性,在基于光学的可穿戴和可植入生物传感器中显示出巨大的潜力。然而,柔性光纤的多模态特性限制了它们与传统光纤传感器的集成。本文首次介绍了一种基于激光干涉技术的柔性光纤振动传感器,可应用于大拉伸条件下的振动测量。该传感器利用聚二甲基硅氧烷(PDMS)制成的弹性光纤作为传感元件,结合相位发生载体技术,在 0~42% 的拉伸范围内实现 50~260 Hz 的振动测量。
关 键 词:可拉伸光纤传感;光纤振动传感器;相位生成载波
中图分类号:O436.1 **文献标志码:**A **doi:**10.37188/CO.EN-2025-0010 **CSTR:**32171.14.CO.EN-2025-0010

收稿日期:2025-02-21;**修订日期:**2025-03-13
基金项目:安徽省重点研发项目(No. 2023Z0420012, No. 1704a0902061);国家自然科学基金(No. 62405003, No. 61705001)
Supported by Anhui Province Key Research and Development Project (No. 2023Z0420012, No. 1704a0902061); Natural Science Foundation of China (No. 62405003, No. 61705001)

1 Introduction

In the field of soft sensors, various conductive nanomaterials such as carbon nanotubes[1], graphene[2], and metal nanoparticles/lines/networks[3] have been widely applied in wearable stretchable sensors. The sensing mechanism of these sensors typically relies on changes in resistance or capacitance induced by deformation, enabling the monitoring of parameters such as temperature, strain, and vibration. Taking the research by Wang *et al*. as an example[4], they developed a flexible sensor specifically designed for dynamic vibration and acceleration monitoring using the piezoresistive effect, which successfully achieved vibration detection in the frequency range of 50−400 Hz. Meanwhile, Wei's team employed a double-layer capacitor structure combined with aerosol jet printing technology using silver nanoparticle ink to fabricate a strain sensor capable of detecting subtle human vibrations[5]. Although researchers have adopted flexible material encapsulation technology to prevent direct contact between electronic components and human biological tissues while maximizing sensor biocompatibility, these measures still fail to completely address the issues of electromagnetic interference immunity and electrical safety in electrical sensors. As an important branch of soft optical sensors[6], stretchable optical fiber (SOF) sensors have attracted much attention due to their unique performance advantages. Not only does it have excellent flexibility and biocompatibility, but it also maintains high mechanical strength and electromagnetic interference resistance comparable to traditional fiber optic sensors. These features make it widely used in fields such as intelligent human-computer interaction, wearable health monitoring, and biomedical research. Research has confirmed that this fiber optic wearable sensor can effectively detect various information such as temperature, tensile deformation, and biomolecules[7-8].

Fiber sensing is achieved by detecting changes in light intensity, phase, and polarization state within the fiber caused by external interference. Similar to traditional silica fibers, SOFs efficiently confine and transmit light via total internal reflection (TIR) using optically resilient materials such as PDMS[9-10], hydrogels[11-12], and thermoplastic elastomers (TPE)[13] which have been widely studied in previous research. Furthermore, due to the stretch rebound properties and light conduction characteristics of flexible fibers, optical waveguide sensors based on these fibers are anticipated to exhibit significant potential for applications in smart wearables and medical treatments. In recent years, the reported sensors combined with soft optical fibers can be divided into three aspects from the sensing strategies. First, the researchers attempted to achieve sensing by measuring the linear relationship between the transmission loss of the waveguide material and the mechanical deformation or bending. For example, step-index fiber prepared by one-step coextrusion process can withstand 300% reversible deformation while realizing large stretch motion detection at human joints[14]. Second, temperature sensitive fluorescent nanoparticles are doped in flexible optical fiber, and fluorescence intensity ratio (FIR) technology is used to realize stretchable optical fiber temperature sensing[15]. Third, functional particles that can specifically recognize chemical molecules or biological hormones are combined with soft fibers to detect changes in transmitted light or fluorescence intensity to determine the concentration of the analyte[16], making it applicable for the specific molecular detection within living organisms such as glucose, blood oxygen, and neurochemicals. It is well known that laser interferometric detection technology has advantages such as high sensitivity and low cost. However, the use of interference techniques for SPOF sensing has not yet been reported.

Here, we propose a new strategy for SPOF sensing by integrating traditional interferometric fiber vibration sensing technology with soft fibers.

The SPOF used is a coreless optical fiber made of PDMS. By connecting two multimode fibers (MMF) to the ends of a 3.8 cm long, 300 μm diameter SPOF and incorporating it into a fiber Mach-Zehnder interferometer configuration, we have devised a SPOF vibration sensor. Phase generating carrier (PGC) technology and phase demodulation algorithms were employed for measuring external vibration signals.

2 Principle

The PGC demodulation optical path structure designed in this article is shown in Fig. 1. The system adopts an externally modulated Mach Zehnder interferometer (MZI) structure to achieve flexible fiber sensing. Specifically, the optical signal output by the laser source is split by a 1 × 2 coupler to form two interference optical paths: the reference arm uses a 2 m long optical fiber tightly wrapped around a PZT piezoelectric ceramic and applies a modulation signal of 5 kHz. The sensing arm adopts MMF-SPOF-MMF composite fiber structure as the sensing unit. After interference, the two optical signals are converted into electrical signals by a high-sensitivity photodetector (PD), and finally digitized by a data acquisition card at a sampling rate of 100 kHz.

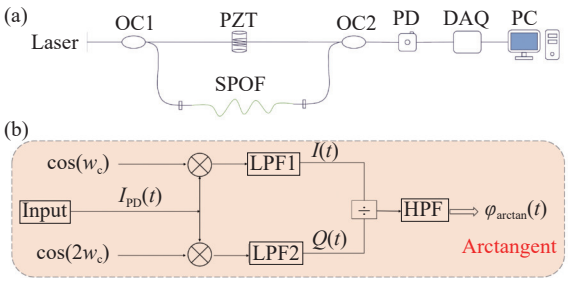


Fig. 1 (a) Structure diagram of vibration sensing system based on SPOF. (b) Schematic diagram of arctangent algorithm

The expression of the interference signal detected by photoelectric is as follows:

$$I_{\mathrm{PD}} = A + B\cos\left[C\cos\omega_{\mathrm{c}}t + \varphi_{\mathrm{s}}(t)\right] \quad , \qquad (1)$$

where A is the direct flow, B is the amplitude of the interference signal, $C\cos\omega_{\mathrm{c}}t$ is the modulated signal applied by PZT, and $\varphi_{\mathrm{s}}(t)$ is the signal to be measured. By expanding (1) according to Bessel function, we get:

$$I_{\mathrm{PD}} = A + B\left\{\left[J_0(C) + 2\sum_{k=1}^{\infty}(-1)^k J_{2k}(C)\cos(2kw_{\mathrm{c}}t)\right]\cos\varphi_{\mathrm{s}}(t) - \left[2\sum_{k=0}^{\infty}(-1)^k J_{2k+1}(C)\cos[2(k+1)w_{\mathrm{c}}t]\sin\varphi_{\mathrm{s}}(t)\right]\right\}, \qquad (2)$$

It can be seen that, after mixing I_{PD} with the modulation fundamental frequency signal $\cos(w_{\mathrm{c}}t)$ and the double frequency signal $\cos(2w_{\mathrm{c}}t)$, and then low-pass filtering the outputs, the sine and cosine terms are obtained respectively:

$$I(t) = -BJ_1(C)\sin\varphi_{\mathrm{s}}(t) \quad , \qquad (3)$$

$$Q(t) = -BJ_2(C)\cos\varphi_{\mathrm{s}}(t) \quad . \qquad (4)$$

In practical operation, we can adjust the modulation depth to make sure that $J_1(C) = J_2(C)$, and then divide and arctangent the filtered $I(t)$ and $Q(t)$ signals to obtain the vibration:

$$\varphi_{\mathrm{s}}(t) = \operatorname{atan}\frac{I(t)}{Q(t)} \quad . \qquad (5)$$

3 Experiment results and discussion

3.1 Fabrication of flexible optical fiber

Fig. 2(a) (color online) illustrates the fabrication process of PDMS SPOF. The detailed procedures are as follows: First, the PDMS prepolymer liquid (base to curing agent ratio 10∶1) is degassed under vacuum for 15 minutes, then injected into a polytetrafluoroethylene (PTFE) tube with an inner diameter of 300 μm using a syringe. Subsequently, two multimode optical fibers with flat end faces are inserted into both ends of the PTFE tube, serving as the light input and output ports respectively. After securing the entire structure, the sample is

cured in an oven at 80 °C for 2 hours. Finally, the PTFE sleeve is peeled off to obtain the MMF-SPOF-MMF optical fiber structure. Multiple measurements have shown that the diameter of the fabricated flexible optical fiber is approximately (345± 5) μm (Fig. 2(b), color online). Fig. 2(c) (color online) displays the surface morphology characteristics of the SPOF, which is formed by thermoplastic processing with its surface morphology entirely determined by the inner wall of the mold. Fig. 2(d) (color online) presents the actual imaging effect of the MMF-SPOF-MMF structure under illumination by a laser pen (760 nm).

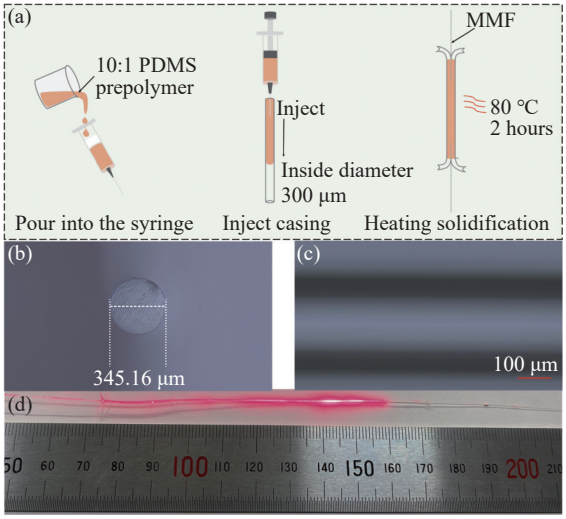
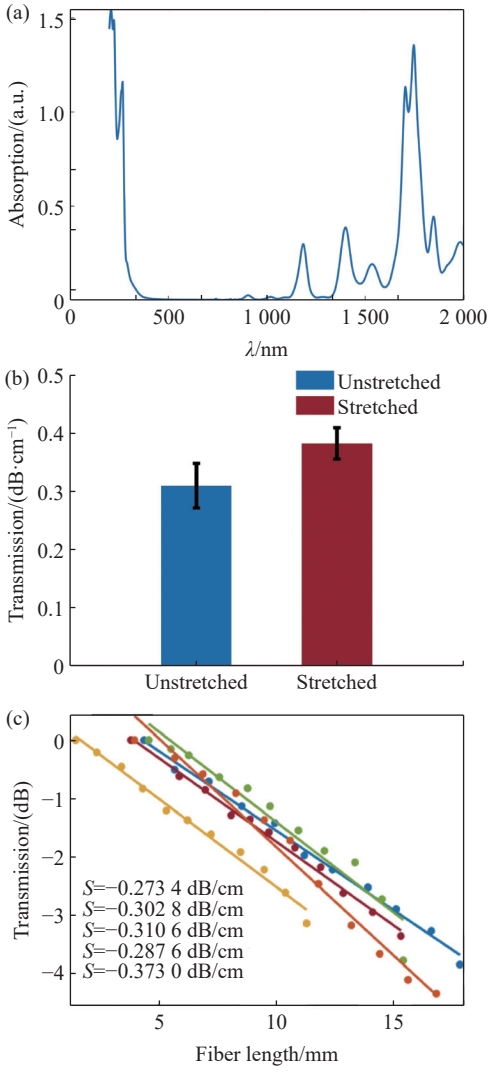


Fig. 2　(a) PDMS SPOF fabrication process. (b), (c) Sectional images and surface morphology of SPOF under optical microscope. (d) MMF-SPOF-MMF structure after demolding

3.2　Mechanical and optical properties

In order to quantitatively evaluate the mechanical and optical properties of the fibers, we carried out tensile test experiments, spectral analysis of transmitted light and measurement of fiber transmission loss.

To characterize the optical properties of PDMS fiber, we first tested the transmission spectrum of PDMS material, and the measurement results are shown in Fig. 3(a) (color online). It can be clearly seen from the graph that PDMS exhibits low optical transmission loss in the wavelength range of 300−1 100 nm. Therefore, we chose a 532 nm laser as the light source for testing and experimentation, and measured the optical loss of SPOF in this band. In the experiment, two sets of SPOF with 5 samples each were used to evaluate the optical loss of SPOF before and after stretching, and the results shown in Fig. 3(c) and 3(d) (color online) were obtained. According to the Lambert-Beer law, as the length of the optical fiber decreases, the intensity of the transmitted light increases exponentially. We consider the linearity between logarithmic propagation loss and fiber length. The attenuation coefficient was extracted from the composite slope, and a loss of approximately 0.3 dB/cm was measured (Fig. 3(b), color online).



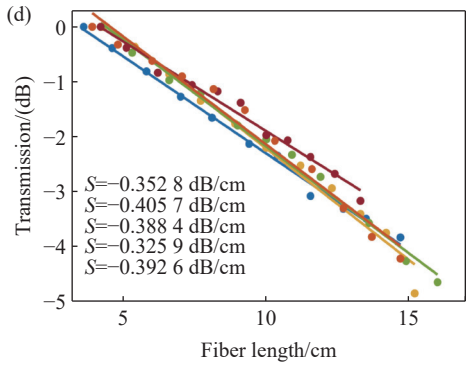


Fig. 3 Mechanical and optical properties of SPOF. (a) PDMS transmission spectrum. (b) Optical loss evaluation of 5 SPOF samples, blue represents the optical loss measured without any testing, and red represents the optical loss measured after 1 000 stretching cycles. (c) Optical loss of SPOF. (d) Optical loss of SPOF measured after 1 000 stretching cycles

In addition, wearable sensors require sensor materials that can adhere to the surface of the body and are relatively easy to achieve large-scale stretching and rapid synchronous contraction. We tested the optical properties of PDMS fiber samples under repeated stretching conditions to verify whether they meet the basic requirements of wearable sensors. Fig. 4(a) (color online) shows the changes in transmitted light intensity measured through 79 consecutive stretching and shrinking cycles.

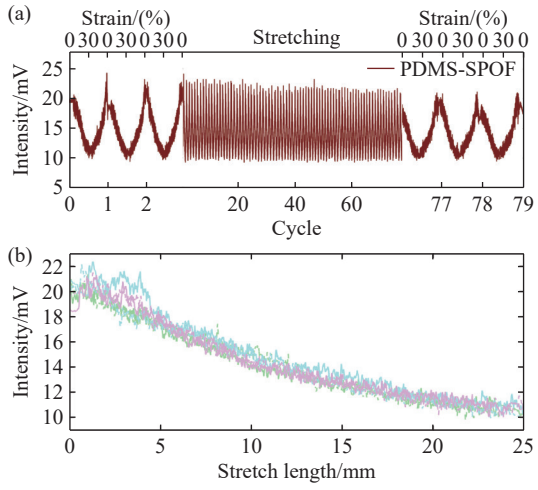


Fig. 4 Mechanical properties of SPOF. (a) The relationship between transmitted light intensity and stretching amount under cyclic dynamic stretching state. (b) The relationship between stretching length and transmitted light intensity

Fig. 4(b) (color online) shows the relationship between the stretching amount and the transmitted light intensity during three micro stretching processes. Obviously, the relationship between mechanical stretching and changes in transmitted light intensity of PDMS fibers during repeated stretching and relaxation processes still exhibits good consistency and stability. Flexible sensing based on this feature has been applied in many reports.

3.3 Vibration detection

The system's vibration sensing feasibility was evaluated by monitoring the interference signal received by the detector. The interference signal detected by PDMS-SPOF during the random disturbance applied by SPOF of the sensing arm is shown in Fig. 5 (color online), from which it can be observed that the amplitude of the interference signal is about 6 mV, which proves that SPOF prepared by flexible materials is expected to realize the sensing function based on optical interference technology. In addition, to achieve the best detection effect, the PD's AC output signal was amplified 100-fold.

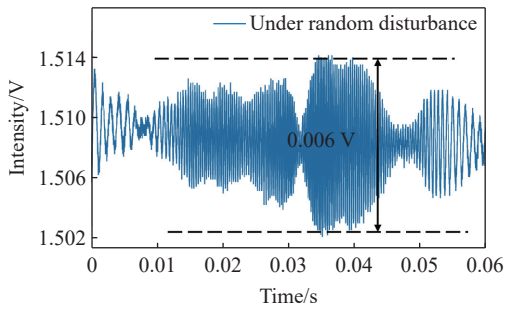


Fig. 5 The interference signal detected by PDMS-SPOF when the random disturbance is applied

To create a stretchable vibration environment, we fix the two ends of the SPOF on the surface of the balloon. In the preparation stage of the experiment, we first select a SPOF with a length of 38 mm as the main sensing element, and fix the SPOF on the surface of the balloon. 3M tape is used to stabilize the position of the flexible optical fiber at both ends on the surface of the balloon, ensuring close contact with the balloon surface and stability in sub-

sequent experiments (note that the tape should avoid vibration interference with the MMF during this process. 3M tape should be fixed at a distance of 1−2 cm from the coupling position of the MMF-SPOF optical path). Then, a speaker is placed 5 cm above the balloon. The speaker will serve as a vibration source, driving the balloon to vibrate by transmitting sound signals of different frequencies, which in turn causes the fiber optic sensor to vibrate on its surface. Fig. 6 (color online) shows the four measured frequency signals of SPOF when it is at its original length and the speaker provides sine signals (Vpp=2 V) at different frequencies (50 Hz, 90 Hz, 180 Hz, and 260 Hz).

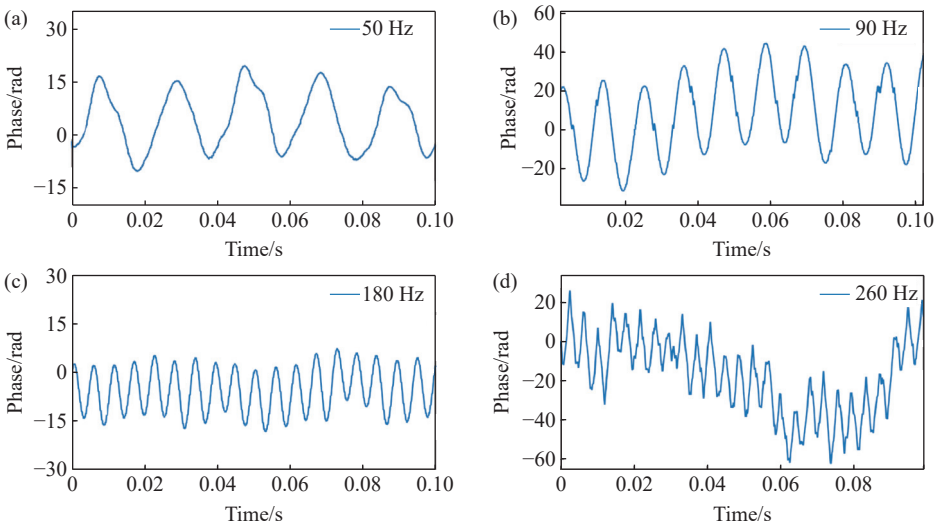


Fig. 6　Phase change response of several representative frequency points at a fixed stretch

From the test results in the Fig. 6, it can be seen that the vibration sensing system based on flexible fiber optic design can accurately recover the vibration signals of four corresponding frequencies on the surface of the object.

When evaluating the integration potential of SPOF sensors into wearable devices, a critical consideration is their capacity to maintain vibration measurement accuracy under cyclic mechanical strain. In order to evaluate the performance of flexible optical fibers for vibration measurement in wearable devices, the research team designed an experiment for the vibration measurement of SPOF under a wide range of stretching conditions. In the experiment, the SPOF was stretched by inflating the balloon with an air tank and causing it to expand. Fig. 7 (color online) shows the relative position of PDMS-SPOF with the balloon before and after expansion.

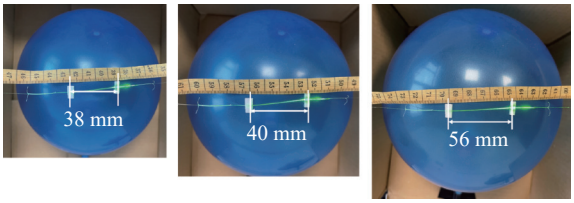


Fig. 7　PDMS-SPOF affixed to the surface of the balloon is used to obtain different stretching amounts of the measured fiber by charging and deflating the balloon

During the process, three different fiber elongation ratios were selected, corresponding to 10%, 26% and 42% of the original length respectively, and the measurement data of different elongation ratios under the same signal to be measured (90 Hz) were collected for analysis and comparison. ΔL represents the length change of the flexible fiber, L is the original length of the flexible fiber, $R = \Delta L/L$ represents the percentage of elongation. Fig. 8 (color online) shows the vibration measurements recorded at different drawing levels. It can be seen that

the vibration measurement system maintains a relatively stable signal-to-noise ratio under the three extensions, the lowest being 8.01 dB at 42% elongation.

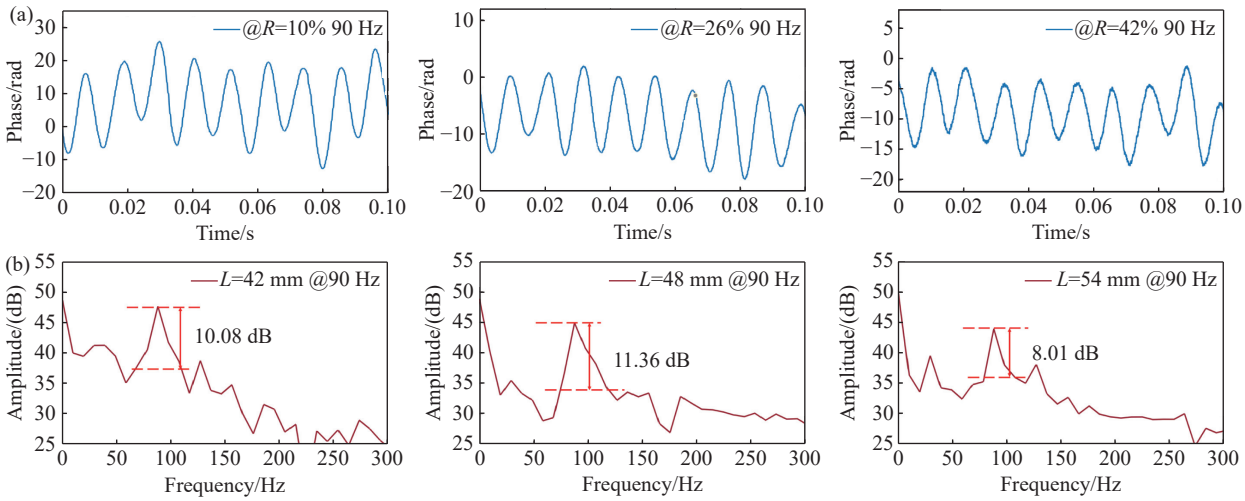


Fig. 8 When the signal to be measured is a 90 Hz sinusoidal signal, (a) the time domain phase change response under different stretching values measured by the SPOF sensor and (b) the frequency domain of the demodulated phase signal

This study still has several limitations that require gradual improvement in future research. Current human vibration sensing experiments have shown that flexible fiber-optic vibration sensing systems have high sensitivity to environmental interference. These interferences mainly manifest in two aspects: firstly, when in contact with the human body, the unconscious small vibrations of the measured object will interfere with the system. Secondly, quartz fiber and SPOF are susceptible to external mechanical interference during the measurement process. In response to these issues, we plan to carry out improvement work in the following aspects: firstly, in terms of material structure, we will strive to develop SPOF with core-clad structures and improve the signal-to-noise ratio by optimizing the fiber waveguide structure. At the same time, we plan to fix SPOF on flexible substrates such as PDMS to improve the mechanical stability of the system and reduce interference caused by human activities. Secondly, in terms of optical path design, we will adopt a reflective optical path structure to improve the existing transmissive sensing optical path. Specifically, the end face reflection at the coupling interface between quartz fiber and SPOF, as well as the reflected light at the end of the SPOF, will be used as reference signals. This design can effectively avoid the impact of interference on the system when multimode optical fibers are affected. Finally, in terms of signal processing, we will introduce intelligent algorithms such as deep learning to more accurately analyze and process signals in SPOF. By establishing a feature library and recognition model for vibration signals, the anti-interference ability and measurement accuracy of the system can be improved in complex environments. Another important direction is to break through the bottleneck of low modulus polymer flexible fiber preparation technology. Due to the strict requirements of traditional interferometric fiber optic sensing for mode characteristics and the inability of existing SPOF fabrication techniques to meet low mode transmission needs, this will become a key research topic in the field of material development. It is worth noting that the intelligent upgrade and miniaturization integration of the system will also be the core direction of future research. By integrating intelligent signal recognition and analysis algorithms, interference signal types can be identified and noise can be filtered out. At the same time, combined with

miniaturized hardware design, the practical value of flexible vibration sensors has been significantly improved, laying a technical foundation for the practical application of wearable monitoring devices.

4 Conclusion

This article proposes the combination of interferometric vibration sensing technology and flexible optical fibers, and attempts to develop a scalable vibration sensor with wearable application potential. To our knowledge, this is the first report on an interferometric vibration sensor based on flexible optical fibers. The sensor consists of a single point optical fiber with a length of 3.8 cm and a transmission loss of approximately 0.3 dB/cm, which is connected to the interferometer optical path via MMF. The optical coupling between flexible materials and quartz optical fibers is achieved through in-situ curing method. Compared to other wearable sensing devices used for sensors, the sensing system we proposed has good response in the range of 50−260 Hz and its strain sensitivity was measured to be ~10 $n\varepsilon/\sqrt{Hz}$@90 Hz under 26% tensile conditions. Compared with similar electrical sensors, SPOF has a relatively close frequency response range. At the same time, it can achieve vibration sensing under different stretching states, as well as the anti-electromagnetic interference capability possessed by traditional fiber optic sensors.

References:

[1] WANG R, SUN L F, ZHU X Y, *et al*.. Carbon nanotube-based strain sensors: structures, fabrication, and applications[J]. *Advanced Materials Technologies*, 2023, 8(1): 2200855.

[2] CHEN H, ZHUO F L, ZHOU J, *et al*.. Advances in graphene-based flexible and wearable strain sensors[J]. *Chemical Engineering Journal*, 2023, 464: 142576.

[3] LIU X H, MIAO J L, FAN Q, *et al*.. Recent progress on smart fiber and textile based wearable strain sensors: materials, fabrications and applications[J]. *Advanced Fiber Materials*, 2022, 4(3): 361-389.

[4] WANG X, ZHOU H Y, CHEN M H, *et al*.. Wearable ultrasensitive and rapid human physiological monitoring based on microfiber Sagnac interferometer[J]. *Science China Information Sciences*, 2024, 67(3): 132403.

[5] WEI W ZH, ZHANG L H, LIAO ZH Y, *et al*.. Aerosol jet printing of advanced capacitive strain gauge for vibration monitoring of the human body[J]. *The International Journal of Advanced Manufacturing Technology*, 2025, 138(1): 31-43.

[6] KAUR B, KUMAR S, KAUSHIK B K. Novel wearable optical sensors for vital health monitoring systems—A review[J]. *Biosensors*, 2023, 13(2): 181.

[7] SONG E H, CHEN M H, CHEN Z T, *et al*.. Mn^{2+}-activated dual-wavelength emitting materials toward wearable optical fibre temperature sensor[J]. *Nature Communications*, 2022, 13(1): 2166.

[8] CHEN M H, HE Y CH, LIANG H H, *et al*.. Stretchable and strain-decoupled fluorescent optical fiber sensor for body temperature and movement monitoring[J]. *ACS Photonics*, 2022, 9(4): 1415-1424.

[9] SHENTU ZH CH, KANG J, ZHU ZH CH, *et al*.. No-core PDMS fiber for large-scale strain and concentration measurement[J]. *Optical Fiber Technology*, 2021, 63: 102531.

[10] GUO J J, NIU M X, YANG CH X. Highly flexible and stretchable optical strain sensing for human motion detection[J]. *Optica*, 2017, 4(10): 1285-1288.

[11] GUO J J, LIU X Y, JIANG N, *et al*.. Highly stretchable, strain sensing hydrogel optical fibers[J]. *Advanced Materials*, 2016, 28(46): 10244-10249.

[12] YETISEN A K, JIANG N, FALLAHI A, *et al*.. Glucose-sensitive hydrogel optical fibers functionalized with phenylboronic acid[J]. *Advanced Materials*, 2017, 29(15): 1606380.

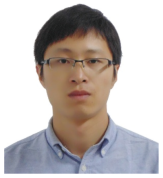
[13] SHABAHANG S, CLOUSER F, SHABAHANG F, *et al*.. Single-mode, 700%-stretchable, elastic optical fibers made of thermoplastic elastomers[J]. *Advanced Optical Materials*, 2021, 9(12): 2100270.

[14] LEBER A, CHOLST B, SANDT J, *et al*.. Stretchable thermoplastic elastomer optical fibers for sensing of extreme deformations[J]. *Advanced Functional Materials*, 2019, 29(5): 1802629.

[15] GUO J J, ZHOU B Q, YANG CH X, *et al*.. Stretchable and temperature-sensitive polymer optical fibers for wearable health monitoring[J]. *Advanced Functional Materials*, 2019, 29(33): 1902898.

[16] ZHOU B Q, FAN K K, GUO J J, *et al*.. Plug-and-play fiber-optic sensors based on engineered cells for neurochemical monitoring at high specificity in freely moving animals[J]. *Science Advances*, 2023, 9(22): eadg0218.

Author Biography:



TU Guo-jie (1981—), male, born in Anqing, Anhui Province, holds a doctor's degree, associate professor's degree and master's supervisor. He obtained a bachelor's degree in science from Anhui University in 2007 and a doctor's degree from Anhui Institute of Optics and Precision Mechanics, Chinese Academy of Sciences in 2012. In the same year, he entered the Optical Communication Engineering Research Center of Nanjing University for postdoctoral research. He started working at Anhui University in 2015 and was promoted to associate professor in 2020. At present, he mainly engages in fiber optic sensing and atmospheric trace gas detection. E-mail: 15041@ahu.edu.cn