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硕 士 学 位 论 文

膜片式 EFPI 光纤声波传感器及传感系统的研究  
Research on Diaphragm Based EFPI Fiber-Optic Acoustic  
Sensor and Sensing System

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## 摘要

光纤声波传感器相比传统的电式声波传感器具有灵敏度高、抗电磁干扰、低传输损耗、重量轻等优势，具有广泛的应用前景。基于膜片式的非本征法布里·珀罗干涉型光纤声波传感器，是目前声波传感器研究领域中最灵敏的一种<sup>[1]</sup>，在其材料选择、结构设计、信号处理和实际应用上是当前各科研机构的研究热点。本文对这种类型的传感器进行了较为深入的研究，主要工作体现在以下几个方面：

一、针对干涉型传感器工作点漂移导致信号衰落的问题，研究了用于信号补偿的双波长正交解调法，将解调方式分类为小信号和大信号两种情况，并分析讨论了这两种情况的适用的膜片振动幅度范围。对于两路信号非完全正交的情况，改进了解调算法，分析并讨论了实际应用中由于信号噪声的存在，相位差偏离完全正交情况下多少范围解调效果好坏的问题。得出结论是在相位差偏离正交情况 $\pm 20^\circ$ 以内时解调后的信号基本不会发生变化，而超过 $\pm 60^\circ$ 以后解调算法基本失效。

二、采用声敏感聚合物薄膜设计并制作了 EFPI 声波传感器，基于双波长解调方案搭建了声波传感系统，测试了传感器的特性并验证了解调理论的可行性。并用传感器对铝板中的超声波进行非接触式检测，实验证明该传感器的检测效果要高于贴附与铝板上的 FBG 型声波传感器。这种检测方式具有较大的应用前景。

三、设计了一种光路结构，该结构基于双波长正交解调法作扩展，用来构造准分布式声波传感系统。该系统能够既实现了准分布式测量，又保持输出信号的稳定。搭建实验系统验证了这种光路的可行性。

**关键词：** 光纤 EFPI 声波传感器，双波长正交解调法，准分布式传感系统

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## Abstract

Compared with the traditional electric acoustic sensor, the optical fiber acoustic sensor has the advantages of high sensitivity, anti-electromagnetic interference, low transmission loss and light weight, and has a wide application prospect. The diaphragm-based Extrinsic Fabry-Perot fiber-optic acoustic sensor is recognized as one of the most sensitive acoustic sensors in the present study so far. The current research focus mainly on its material selection, structural design, signal processing and practical application. In this paper, this type of sensor and its system was studied, the main work is reflected in the following aspects:

(1) In order to solve the problem of signal fading caused by the drift of the working point of the interferometric sensors, the dual-wavelength orthogonal demodulation method for signal compensation is studied. The demodulation method is classified into two cases: small signal and large signal. And the application range of the diaphragm vibration amplitude of the two cases is analyzed and discussed. For the situation that the two signals are not completely orthogonal, the demodulation algorithm is improved. We discussed and analyzed the relationship between the demodulation effect and the phase difference in the presence of noise in the signals when it comes to practical application. It is concluded that, when the phase difference deviates from the orthogonal condition within  $\pm 20^\circ$ , the signal after demodulation is basically the same. And when the value is over  $\pm 60^\circ$ , the demodulation method is basically ineffective.

(2) An EFPI acoustic sensor is designed and fabricated by using the acoustic sensitive polymer film. The acoustic sensing system is built based on the dual wavelength demodulation method. The characteristics of the sensor are tested and the feasibility of the demodulation theory is verified. And the sensor is used to detect the ultrasonic wave in an aluminum plate. The experiment proves that the detection effect is higher than that of an FBG type acoustic sensor attached to the aluminum plate. This

kind of detection method has a great application prospect.

(3) An optical path structure is designed, which is extended based on the dual-wavelength orthogonal demodulation method, for the construction of quasi-distributed acoustic sensing system. The system can achieve not only quasi-distributed measurement, but also the stability of the signals after demodulation. The experiment verifies the feasibility of this system.

**Keywords:** Extrinsic Fabry-Perot fiber-optic acoustic sensor; Dual-wavelength orthogonal demodulation method; Quasi-distributed sensing system

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