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单根光纤布拉格光栅横向受力自动判断研究

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摘　要

单根光纤布拉格光栅在一定的横向压力下中心波长处的光功率大小及中心波长会发生人眼能判断的变化。通过编写代码来读取光谱仪输出的数据，程序代码对输出的数据进行可视化并且和未受到横向压力时的光纤光栅光谱进行对比，在对受到横向压力光纤光栅的中心波长处的光功率和未受到横向压力光纤光栅中心波长处的光功率进行比较大小，可识别出受力光栅和光谱仪显示的受力的光栅结果一致，此结果与光栅已受力的实际情况相符。

关键词

光纤布拉格光栅，横向受力，自动判断

Study on Automatic Judgment of Transverse Force of Single FBG

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Abstract

Under certain lateral pressure, the optical power and central wavelength of a single fiber Bragg grating at the central wavelength will change as judged by the human eye. The output data of the spectrometer is read by writing code. The output data are visualized by the program code and compared with the spectrum of the fiber grating without transverse pressure. The optical power at the central wavelength of the fiber grating under transverse pressure and the optical power at the central wavelength of the fiber grating without transverse pressure are compared. The results of the stress grating and the grating displayed by the spectrometer are consistent, which is con-

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sistent with the actual situation of the grating.

Keywords

Fiber Bragg Grating, Transverse Force, Automatic Judgment

1. 引言

光纤布拉格光栅(FBG)传感器由于具有响应速度快、成本低、抗干扰、兼容性强、性能稳定等优点使它在通信领域和光学传感领域受到广泛的关注[1] [2] [3]。基于这些优点使FBG在生活中得到大量的应用，如压力、位移、应变等参数的测量[4] [5] [6] [7]。FBG在生活和工业中应用也十分广泛，如健康监测[8]、测量流速[9]、制作光纤激光器[10]、检测和定位撞击位置[11]、倾斜检测装置[12]等。目前对光纤光栅的应力和应变的研究，大多数文献报道都是光纤光栅轴向方向的研究[13] [14]。由于光纤光栅横向应力使光纤光栅发生形变导致双折射[15]，但FBG的反射光谱变化不是十分明显，因而关于FBG横向应力传感的研究相对较少。有些科学家们发现可以使用 FBG 的偏振相关损耗(PDL)性质可以进行横向应力的测量[16]，因为偏振相关损耗对横向压力的具有很好灵敏度，所以光纤光栅这种横向应力的测量方法具有很高的研究价值。Descamps等研究了一种利用啁啾光纤光栅(CFBG)偏振相关损耗谱估计横向负载分布的方法[17]，该方法利用了啁啾光纤光栅偏振相关损耗的积分与力分布之间的关系，其优点是不需要任何迭代方法来估计横向载荷分布。Wang等提出了一种利用FBG偏振特性进行温度不敏感横向负载传感的新方法[18]，从理论和实验上研究了光纤光栅的偏振相关损耗随传输信号波长随横向载荷的变化规律。Li 等提出并演示了一种新颖且简单的波长可切换多波长掺铒光纤(EDF)激光器[19]，其基于级联FBG作为波长梳状滤波器的偏振相关损耗调制。Su等研究了局域压力下 FBG 偏振相关损耗的光谱特性，并分析了二次峰的演化[20]，详细研究了负载大小、负载长度和负载位置对产生的二次峰的振幅和波长的影响，采用基于改进传递矩阵法的数值模拟方法计算了光纤光栅的传输和PDL响应。Wang等提出并实验验证了一种利用pi相移布拉格光栅(pi-FBG)偏振特性进行横向负载传感的新技术[21]，研究了pi-FBG偏振相关损耗的光谱特性，分析了pi-FBG的PDL响应随横向载荷的变化规律。Xu等对倾斜光纤布拉格光栅的偏振特性进行了理论研究并推导计算了不同倾角倾斜光纤布拉格光栅的波长相关偏振相关损耗表达式[22]。Lu等讨论了光纤布拉格光栅的波长相关偏振相关损耗特性[23]。我们希望在上述研究基础上，通过程序自动判断光栅是否受到横向压力。

2. 横向受力特性简析

FBG横向压力作用示意图如图1所示，光纤光栅横向受力方向为y，纵向方向为x，光纤光栅轴向为z。当光纤光栅y方向受到外部均匀压力时，光纤光栅发生形变导致x和y方向折射率都发生变化，从而产生双折射现象。由于光纤光栅中的双折射，将导致其透射光谱、反射光谱将对应发生变化。

3. 单FBG横向受力实验设置

单光纤光栅横向受力的实验系统图如图2所示，光由ASE发出，经过单根FBG后进入光谱分析仪。

其中光谱分析仪最小分辨率为 0.02 nm。本次实验使用的光源是 ASE100，它的输出功率为 13.5 dB，它产生波长的光源区间为 1528 nm~1610 nm。

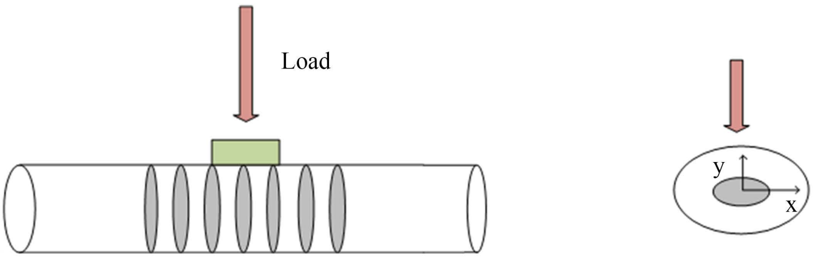

Figure 1. Diagram of FBG transverse pressure action
图 1. FBG 横向压力作用示意图

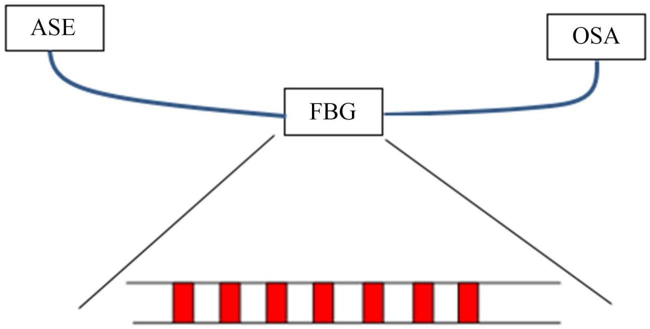

Figure 2. Single FBG transverse force experimental system diagram
图 2. 单 FBG 横向受力实验系统图

进行实验时，将 FBG 平放在表面光滑平整的塑料板上，在光栅上面垂直于光栅放置两根小钢针，光栅上面的钢针通过木板上的重物来对光栅施加横向压力，另一根光栅位于光纤上，为木板提供平衡作用。在两根钢针上面放置一块平整的平板，在平板上在放置重物来实现给 FBG 施加横向压力，如图 3 所示。

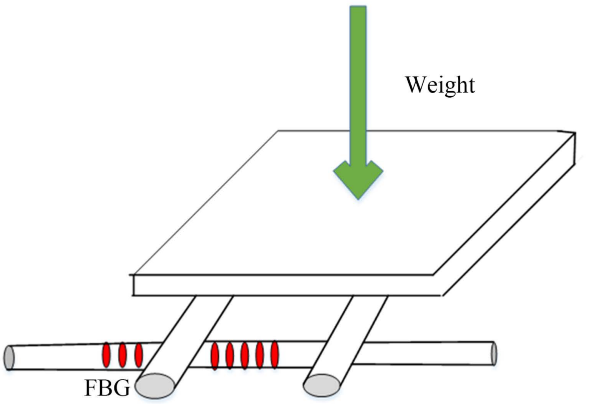

Figure 3. FBG transverse force diagram
图 3. FBG 横向受力示意图

实验所使用的光纤光栅在室温的中心波长为 1547.7800 nm。光栅的长度为 10 mm，带宽是 0.2 nm，受力位置在光栅中间处。

4. 单根 FBG 横向受力实验结果及受力自动判断

在图 3 所示实验情况下，当重物为 1 kg 时，FBG 透射谱在 1547.78 nm 处的透射光功率变化了 4.6 dB。

我们编写代码来读取光谱仪输出的数据，并通过代码进行数据分析和可视化。代码识别光栅受力与否的流程图如图 4 所示。执行的代码使用 python 语言通过 Jupyter Notebook 编程来实现。阈值设定为 2 dB，如果大于此值则判定光栅受力，小于此值则判定光栅未受力。通过比较与阈值的相对大小实现判断光栅是否受力。

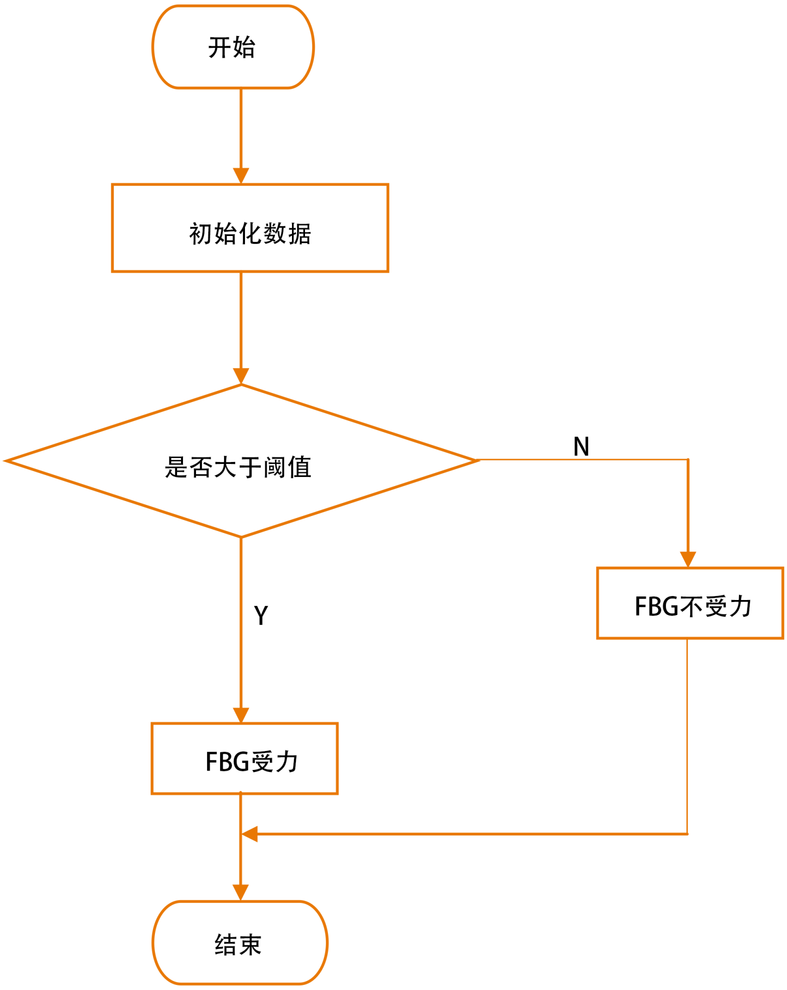

Figure 4. Code identification flowchart
图 4. 代码识别流程图

程序运行结果表明，当给光栅施加上实验中的压力时程序判定 FBG 受到横向压力。这与光谱仪上光谱变化情况相符，也与我们实际实验施加压力过程相符。

5. 结论

我们搭建了一种 FBG 横向受力的实验装置及自动判断 FBG 是否受力的系统，通过程序自动判断光栅是否受到横向压力，它具有一定的工程价值。单根光栅未受到横向压力时光谱仪显示的是一段光滑的曲线，当光栅受到横向压力时，光栅中心波长处的透射光谱会发生明显的变化，通过对比光栅受力前后

中心波长处的光功率变化来判断光栅是否受到横向压力。运行程序结果表明，程序自动判断光栅受到横向压力的结果与光谱仪上的光谱变化一致，也与实际上光栅是否受力情况一致。这表明我们的方法具有一定可行性。

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