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Photo-Thermal Effect in UV-Written Fiber Bragg Gratings

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Abstract A novel method for measuring the photo-thermal effect of fiber Bragg gratings (FBGs) is presented. The photo-thermal effect of an UV-written FBG is studied by using the novel method. A distributed Bragg reflector (DBR) fiber laser is built up by using a 980-nm semiconductor laser as the pump laser, two UV-written FBGs as reflector and a 10-m-long Er-doped fiber as the gain medium. The reflection optical spectrum of the FBG used is obtained while the DBR fiber laser is working. The experimental result shows that the optical reflection spectrum of the FBG shifts by 0.034 nm towards longer wavelength when the pump power is 100 mW, which is induced by the photo-thermal effect. The novel method is applicable in measuring the photo-thermal effect of FBGs.

Key words fiber optics; photo-thermal effect; UV-written; fiber Bragg gratings; absorption; distributed Bragg reflector

OCIS codes 050.2230; 060.3738; 060.2270

紫外写入光纤布拉格光栅的光-热效应

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摘要 提出了一种测量光纤布拉格光栅的光-热效应的新方法，并利用它对一个实际的紫外写入光纤布拉格光栅的光-热效应进行了实验研究。利用980 nm半导体激光器作为抽运源、两个紫外写入光纤布拉格光栅作为反射镜、一段10 m长的掺铒光纤作为增益介质，构建了分布布拉格反射光纤激光器。通过合理设计，在分布布拉格反射光纤激光器工作的同时，获得了所使用的光纤布拉格光栅的反射光谱。实验结果显示，当抽运功率为100 mW时，光-热效应导致所使用的紫外写入光纤布拉格光栅的反射光谱向长波长方向漂移了0.034 nm。该方法可以很好地应用于光纤布拉格光栅的光-热效应的测量。

关键词 光纤光学；光-热效应；紫外写入；光纤布拉格光栅；吸收；分布布拉格反射

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1 Introduction

UV-written fiber Bragg gratings (FBGs) and FBG based devices have been widely used in the optical communication, information processing and sensor systems for their fiber compatibility, low insertion loss and low cost, etc[1-2]. However, during writing the FBG, UV-induced loss will be introduced which is much larger than that in single-mode fiber (about 0.2 dB/km), and it can't be ignored in some cases. Normally, the UV-induced loss includes absorption loss, scattering loss and transition loss[3-6]. The UV-induced absorption loss will lead to photo-thermal heating of the grating which may affect the grating characteristics, shifting the resonance of FBG based devices.

Photo-thermal effect of UV-written FBGs in rare-earth fiber and optical fiber has been investigated[7-8] and exploited[9-10] in the past recent years. In previous articles, the light injecting into the FBG is off-resonant. In this paper, the photo-thermal effect in UV-written FBG is examined by building up a distributed Bragg reflector (DBR) fiber laser using FBGs and Er-doped fiber (EDF). The reflection spectrum of the FBG is obtained while the

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laser is working, which demonstrates the photo-thermal effect directly and intuitively.

2 Experimental Setup

Figure 1 shows the experimental setup which is used to investigate the photo-thermal effect in UV-written FBGs. The left part of the experimental setup is a DBR fiber laser by using two FBGs (FBG1 and FBG2) and a 10-m-long EDF. A 980-nm semiconductor laser was used as the pump laser. The FBGs were written in the hydrogen-loaded corning SMF-28 fiber by using the KrF excimer laser which was working at 240 nm. The Bragg wavelength and maximum reflectivity of FBG1 are 1555.035 nm and 98.2%, respectively. The Bragg wavelength and maximum reflectivity of FBG2 are 1555.043 nm and 99.7%, respectively. A broad band light source (BBLS) and a three-port circulator were used to measure the optical reflection spectrum of FBG2. The optical spectrum was measured by an optical spectrum analyzer (OSA, ANDO AQ6317C).

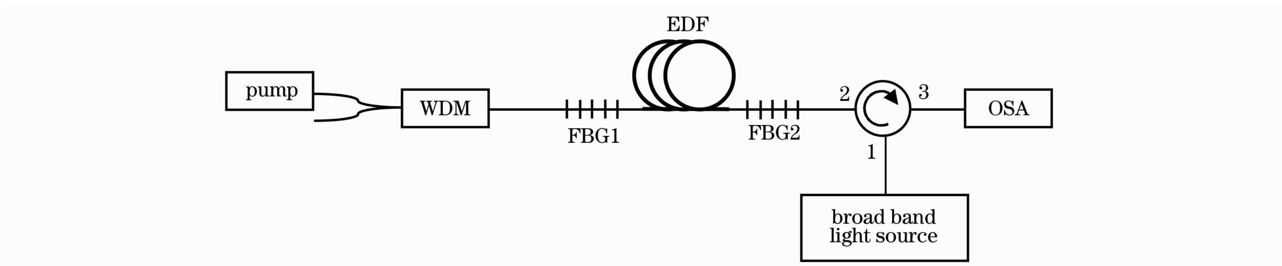

Fig.1 Experimental setup for measuring the photo-thermal effect in UV-written FBG

Figure 2(a) and (b) show the measured optical reflection and transmission spectra of the FBG1 and FBG2 by using the BBLS. It's worth nothing to indicate that the reflection spectrum here is not the real reflection spectrum of the FBG. The real reflection spectrum of the FBG can be calculated by using the transmission spectrum of the FBG. But the optical reflection spectrum here is correlative with the real reflection spectrum and transmission spectrum of FBGs. The minimal value of the optical reflection spectrum corresponds to the maximum value of the transmission optical spectrum (−34.576 dBm at 1555.155 nm for FBG1 and −33.104 dBm at 1555.165 nm for FBG2, respectively), just as the double arrow lines in Fig.2 (a) and (b).

After the experimental setup in Fig.1 was built up, the reflection spectrum of FBG2 was measured again and Fig.2(c) shows the result (dashed curve). Also the previous reflection spectrum, which was measured before the experimental setup was built up, is shown in Fig.2(c) (solid curve), there are some differences between the two reflection spectra. After the setup was built up, the reflection power is a little higher than that before the setup was built up; there is a reflection peak within the reflection bandwidth after the setup was built up. Both the changes are due to the Fabry-Perot effect when the two FBGs were spliced together.

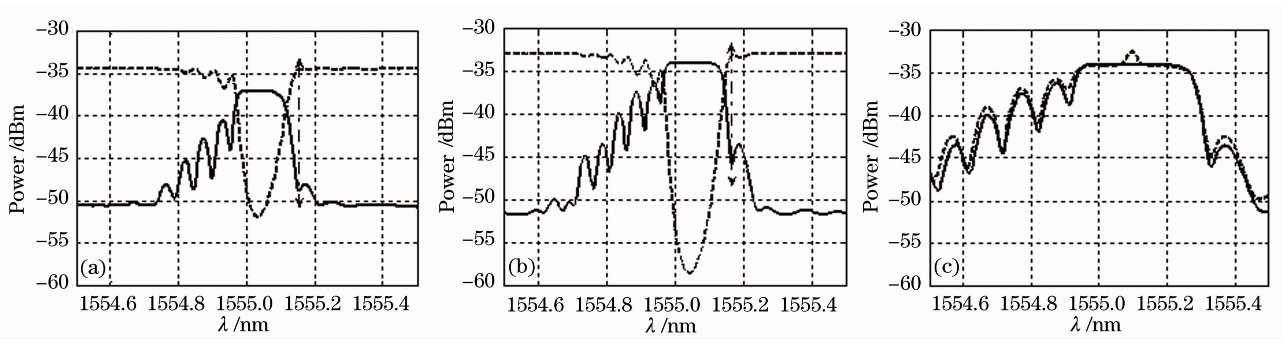

Fig.2 (a) Measured optical reflection (dashed curve) and transmission (solid curve) spectra of FBG1; (b) measured optical reflection (dashed curve) and transmission (solid curve) spectra of FBG2; (c) measured optical reflection spectra of FBG2 before (solid curve) and after (dashed curve) the experimental setup was built up

3 Experiment on the Photo-Thermal Effect in UV-Written FBGs

The experiment includes three steps: 1) both the pump laser and the BBLS were turned on, thus the spectrum recorded with the OSA contained the laser spectrum and the reflection spectrum of FBG2, which is named Record 1 (solid curve in Fig.3); 2) kept the pump laser on and turned off the BBLS, so the spectrum recorded by the OSA was only the laser spectrum, which is named Record 2 (dashed curve in Fig.3); 3) the reflection spectrum of FBG2 can be obtained by subtracting Record 2 from Record 1 (dot curve in Fig.3). The obtained reflection spectrum here is not as flat as that measured in Fig.2, probably because the laser power within the reflection bandwidth is much higher than that of the BBLS.

When we took the reflection spectra of FBG2 obtained in Fig.3 and Fig.2(c) together, just as Fig.4 shows, the wavelength shift can be seen clearly. In Fig.4, the optical reflection spectrum shifted by about 0.034 nm when the pump power was 100 mW.

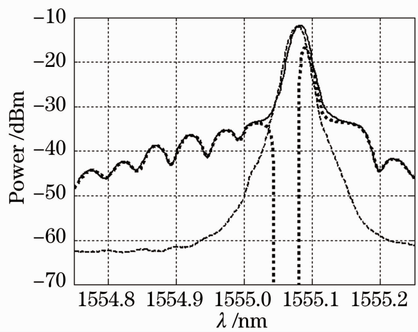

Fig.3 Solid curve shows the optical spectrum containing the laser spectrum and the reflection spectrum of FBG2 (Record 1). Dashed curve only shows the laser spectrum (Record 2). Dot curve shows the reflection spectrum of FBG2 which is calculated by subtracting Record 2 from Record 1

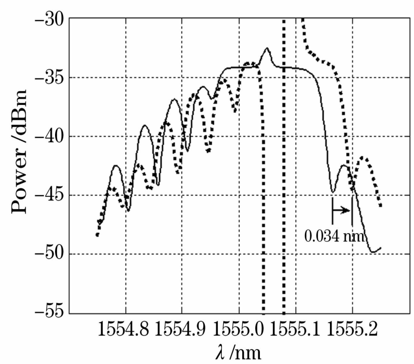

Fig.4 Reflection spectra of FBG2 obtained when the pump power was 0 (solid curve) and 100 mW (dot curve)

We repeated the above experiments but with FBG1 and FBG2 completely immersed in water to keep FBGs at room temperature. Stable reflection spectrum was obtained when the pump power was varied from 0 to 100 mW and no wavelength shift was observed. This confirms that the shift of the spectrum is entirely due to the photo-thermal effect of the fiber.

4 Conclusions

Photo-thermal effect in an UV-written FBG was investigated experimentally by building up a DBR fiber laser using two UV-written FBGs and an EDF. When pumped with power of 100 mW by a 980-nm laser, the reflection spectrum of the investigated FBG shifted by about 0.034 nm. Thus, it shows that the novel method presented here could measure the photo-thermal effect of FBGs efficiently. Also, since the UV-induced absorption could not be ignored for an UV-written FBG, photo-thermal heating may occur, which is significant in grating based fiber optics devices. When using such elements, efficient conduction pathways must be taken into account.

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