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Fabrication of Long-Period Fiber Grating using He-Cd Laser

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ABSTRACT

Fiber grating, as an electro-optic component, has been used as a sensor in communications, Internet and various optical applications. The long-period fiber grating has been proved to be a useful optical component for source stabilization, strain gauges, and selective filters. This research develops an enhanced production method and studies the characteristics of long-period fiber gratings. A low power, dual band 325/442 nm, continuous wave He-Cd laser, substituting the conventional high power excimer laser with 248 nm, is employed as a light-source. Fiber gratings were fabricated "point by point" using a computer-controlled process. Various long-period fiber gratings were produced with different exposure times and grating lengths. The transmittance spectra of the gratings were acquired by illuminating white light source. The derivation of the theory coincides with the spectra.

Key words: *Fiber grating, He-Cd laser, point-by-point method.*

I. Introduction

Fiber gratings have been used as strain, temperature, refractive index and bend sensors, which possess high sensitivity, low back reflections, and can be easily fabricated with UV light exposure. They can also be used in numerous applications, such as gain-spectrum flattening, and amplified spontaneous emission filtering. The long-period fiber grating has proved to be a useful optical component for source stabilization, strain gauges, and other applications. Previously, long-period gratings [1] have been fabricated by hydrogen-loaded germanosilicate fibers exposed to 248 nm of UV radiation from a KrF excimer laser, using the grating mask method. However, the strong excimer laser at 248 nm has caused the back-reflection-induced source oscillations, and it will add to the overall cost of improving the optical system. Moreover, the strong absorption of 240 nm light in the fiber's core causes a thermal reaction with the molecular hydrogen in the fiber [2]. This increases the saturated index change and substantially reduces the contrast of the final grating and the strength and integrity of the sensor.

In this article, we propose the point-by point fabrication of a long-period fiber grating using a low power, dual band 325/442 nm, continuous wave He-Cd laser. The principal advantage of writing gratings using the point-by-point technique is flexibility. The grating period is easily controlled and grating structures which chirped periods or apodized coupling coefficients are possible. To the best of our knowledge, this method is the first demonstration of long-period gratings produced by a He-Cd laser at 442 nm.

II. Theory

The long-period fiber grating periodic structures couple the guided fundamental mode to the forward propagation cladding modes. The phase matching condition between these two modes is determined using [3,4,5],

$$\beta_{01} - \beta_{ci}^{(p)} = \frac{2\pi}{\Lambda} \quad (1)$$

Where β_{01} and $\beta_{cl}^{(p)}$ are the propagation constants of the fundamental mode and the cladding modes. The superscript denotes the order of the mode. These coupling modes decay rapidly as they propagate in the fiber. Since the coupling is wavelength-dependent, several discrete notches are produced in the grating transmission spectrum. The spectral characteristics of the fiber grating depend upon the grating period, length, and refraction change index. The wavelength separation between the consequent modes can be approximated using [3],

$$\delta\lambda_{p,p+1} \approx \frac{\lambda_{cut}^{3}}{8n_{cl}(n_{eff} - n_{cl})} \frac{(2p+1)}{a_{cl}^{2}} \quad (2)$$

where a_{cl} is the cladding radius.

III. Experimental Setup

The point-by-point long-period grating is written using an ultraviolet light generated by He-Cd, which is a continuous wave, doubled-frequency (325 nm and 442 nm) and low power (20 mW and 80 mW respectively) laser. The experimental setup for grating fabrication is shown in Fig.1. The Ge-doped QPS-PFBG-1355-T single mode, step-index photosensitive fiber with core and cladding diameters, was chosen for these experiments. In order to enhance the photosensitivity of the core, hydrogen loading was implemented for 7 days. The loading process, in which molecular hydrogen was loaded into the fiber with high-pressure, enabled the UV light to react with every germanium atom, therefore increases the index change in the core. The grating is written by focusing He-Cd laser through a pinhole onto the photosensitive fiber core. A microscope objective lens (20X) images the pinhole (50 μm aperture) onto the core of the optical fiber to produce the desired periodic pattern. The objective of the pinhole is attached using a computer-controlled translation stage, in order to move step by step.

IV. Results

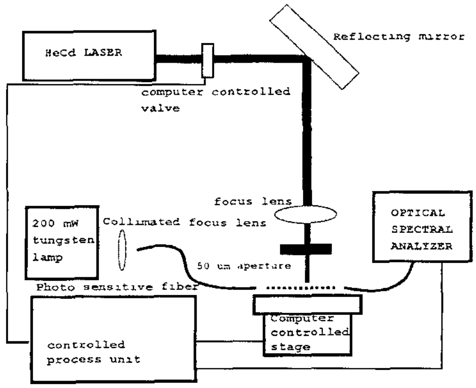

Fig. 1 The setup for long period grating fabrication.

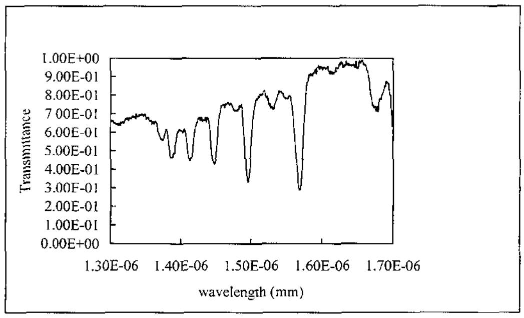

Fig. 2 The transmittance of a long period grating for Λ=200 μm.

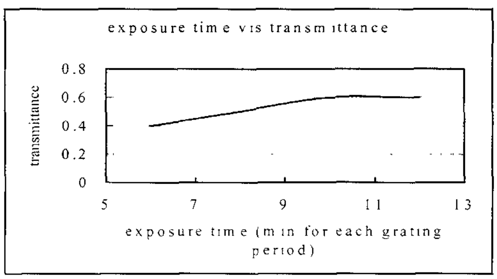

Fig. 3 The transmittance of different exposure time at the same period Λ=200μm.

Fig. 2 shows the transmittance of a long-period fiber grating (LPG) with a grating period Λ=200 μm. This was produced using an exposure time of 10 min. for each step. The total number of grating periods for the LPG is 70 steps. The largest absorbency at matching wavelength is about 85 %. The transmittance spectra of the gratings written with a period Λ=200 μm, 70 steps, with different exposing time 6, 8, 10, and 12 minutes are shown in Fig.3. This indicates that the transmittance changes with different exposure times, while the

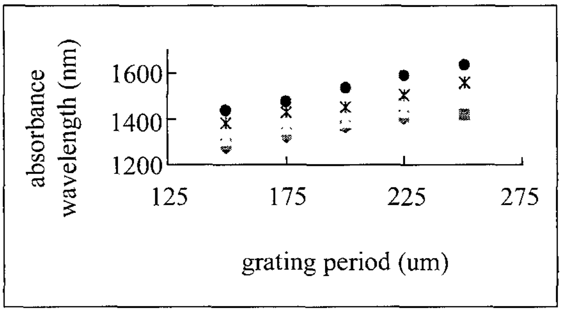

Fig. 4 The absorbance of the five different grating periods LPG, Λ=150, 175, 200, 225, 250μm.

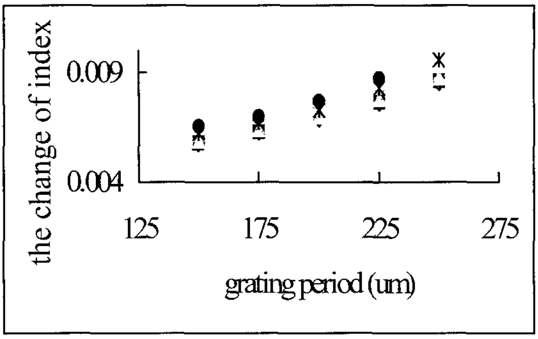

Fig. 5 The index change of the five different grating periods LPG, Λ=150, 175, 200, 225, 250μm.

phase matching wavelength is constant. Fig.4 shows the absorbance of the five different LPG grating periods, Λ=150, 175, 200, 225, 250 μm. Fig. 5 shows the change in the refraction index. The average index change is about 6.8×10^{-3}. In comparison with the previous work [6], the change improvement is almost twice. The spacing is calculated using Eq. (2). The difference between the prediction and experience is less than 20 %. The fiber was tested 3 months after formation. The change in transmittance cannot be observed.

V. Conclusion

In conclusion, we have developed a method for producing long-period fiber gratings, using dual bands 352/442 nm, 100 mW, continuous wave, He-Cd laser, exposing the hydrogen loaded photosensitive fiber. We have found that the phase matching wavelength does not shift during different exposure times. The index change is about 6.8×10^{-3}, thus, using a long wavelength source, a large index change is achieved, viewed over a broad wavelength range.

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以氦鎘雷射製作長週期光纖光柵

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摘　要

光纖光柵依其結構及工作原理的差異，可分為穿透式長週期光纖光柵及反射式布拉格光纖光柵兩種。近年來所發展出的長週期光纖光柵經發現在感測應用上，其溫度、應力的感測靈敏度均比布式光纖光柵高，使其應用價值具有相當的潛力。本實驗採用功率較低、波長較長之連續式氦鎘雷射為曝曬光源，以取代一般研究報告常用之高功率準分子雷射，並配合電腦自動控制精密移動平台，以逐點燒寫的方法製作長週期光纖光柵。同時完成了自製長週期光纖光柵之特性探討，其中包括不同曝曬時間、不同光柵週期及不同光柵長度的光纖光柵製作，及其穿透頻譜的量測，其結果均與理論相符合。

關鍵詞：光纖光柵、氦鎘雷射、逐點燒寫方法。