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Bragg grating device fabrication in undoped PMMA mPOF at 266 nm UV wavelength

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***Abstract*—We present the first results about Bragg grating devices in undoped PMMA POF fabricated with relative low cost Nd:YAG laser (when compared with excimer lasers) at 266 nm wavelength at low transmission loss in 850 nm region. Then temperature, humidity and strain characterizations are supplied for potential applications.**

***Keywords*—Bragg grating, polymer optical fiber, UV irradiation**

I. Introduction

Polymer optical fibers (POFs) show attractive characteristics when compared with silica fiber such as low Young's modulus, high flexibility , high failure strain, bio-compatibility, among others [1]. Different kinds of plastic material can be used for POF fabrication with unique advantages besides PMMA, which is the most common material with low cost [1]. Bragg grating devices based on POF is the most promising technology for POF sensing, where the first POF Bragg grating devices was obtained by *Peng's* group [2] in 1999. Since then, a large number of papers have been reported with significant achievements at this area. Due to the low photosensitivity of PMMA material, different kind of dopants are used to improve the photosensitivity of the POF, such as benzyl dimethyl ketal (BDK) [3], or Trans-4-stilbenemethanol (TS) [4]. The drawback of the dopants usage is the increase of the transmission loss. From this point of view, undoped POFs are more promising due to lower losses compared with the doped ones.

Apart from fibers with different materials and dopants inside, fabrication laser systems are also important for grating devices, where the research of this area grown up so fast recently. In 1999, *Peng et al.* [2] used two illumination wavelengths (248 and 325 nm) for grating fabrication. Since then, continuous wave low power He-Cd 325 nm was the prefer wavelength for fabrication grating devices in POF with affordable and accessible performance. Later, different kind of laser systems with different wavelengths are used for POF grating fabrication. The fabrication of Bragg grating in undoped POFs could be a time-consuming process, to obtain a strongly reflective signal in step index PMMA POF where the minimum inscription time is about 20 mins [5], and in mPOF it could be short to 7 mins [6]. Bragg grating devices were obtained with 248 nm wavelength KrF system with less than 30 seconds [7]. However, this laser system is bulk and expensive. Recently, *Luis et al.* [8] demonstrated one 8 dB Bragg grating with BDK doped mPOF use one short pulse with relative low cost Nd:YAG laser at 266 nm. Unfortunately, no any result was mentioned with undoped PMMA mPOF. Here, we present the first experiment results about Bragg grating devices fabrication with undoped PMMA mPOFs with two hexagonal rings using a low cost Nd:YAG laser at 266 nm wavelength. Additionally, the characterization to the strain, temperature and humidity are supplied for potential sensing applications.

II. Bragg Grating Fabrication

Two hexagonal rings undoped mPOF is used for grating devices fabrication, which was fabricated at *DTU Fotonik*. Figure 1 shows the end face of two hexagonal rings mPOF in which the average hole diameter and the pitch in the fiber are 1.70 μm and 3.95 um, respectively. The sample were pre annealed during 12 hours at 70 ºC to reduce the internal stress in the fiber introduced from the fabrication process.

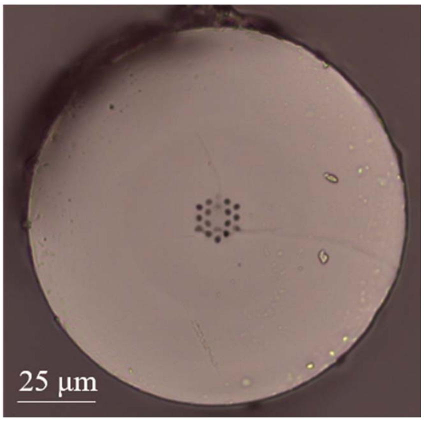

Fig. 1. End face view of two rings mPOF.

Figure 2 presents the grating devices inscription setup. A pulsed Q-switched Nd:YAG laser system (LOTIS TII LS-2137U Laser) lasing at the fourth harmonic (@266 nm) was employed to produce the Bragg gratings, using pump lamp repetition rate of 5 Hz and the Q-Switch mode as single shot. The laser beam profile is circular, the diameter is about 8 mm and the divergence is ≤1.0 mrad. The laser beam is focused

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onto the fiber core using a plano-convex cylindrical lens with effective focal length of 320 mm. The effective spot size of the beam on the fiber surface is 8 mm in width and about 30 µm in height. Experimental setup was aligned and tested before the inscription in order to focus the UV beam onto the core of the fiber and obtain an effective POFBG inscription. The employed phase mask is 10 mm in length with a period of Λ_{PM} = 567.8 nm, designed to operate at 248 nm wavelength.

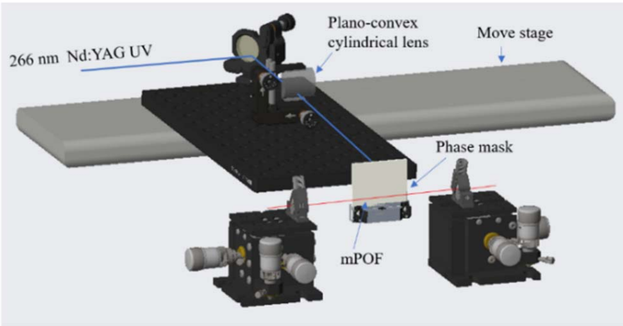

Fig. 2. Laser irradiation system.

The reflected power has been monitored with this kind of fiber as shown in Figure 3. We can observe a Bragg grating device with ~22 dB of reflectivity using 5 Hz of frequency during 220 seconds. Due to the fiber was placed with some tension on the inscription setup, also the humidity and the temperature change, the central wavelength shift to ~841 nm after stable.

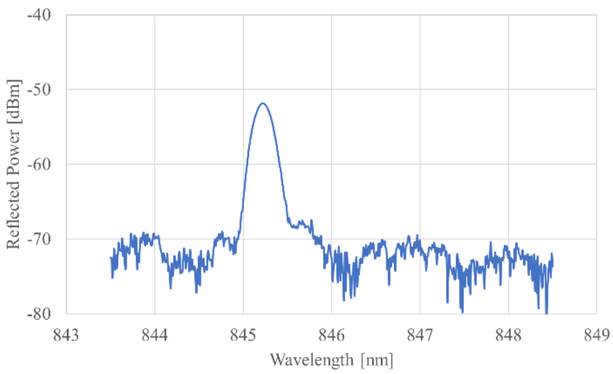

Fig. 3. Reflected spectrum of Bragg grating in two ring mPOF.

III. Temperature and Strain Performance

Here, we report the full characterization of the Bragg grating in two ring structure mPOF in terms of temperature, strain and humidity. Temperature sensitivity of the grating was measured by using a Peltier plate, which contains a small v-groove where the temperature is set with a thermo-electric controller. Silicone grease was placed on the grating position to increase temperature conduction. The central wavelength of the grating was measured from 22 ºC to 52 ºC, in 5 ºC steps, every 10 min. As Figure 4 shows, the total central wavelength shift of Bragg grating device was about 1.16 nm, allowing to estimate a sensitivity of -39±2 pm/ºC. The result a slight highly compared with [9], probably due to the different pre annealing method and annealed in water at 65 °C for 5 days was implemented in [9].

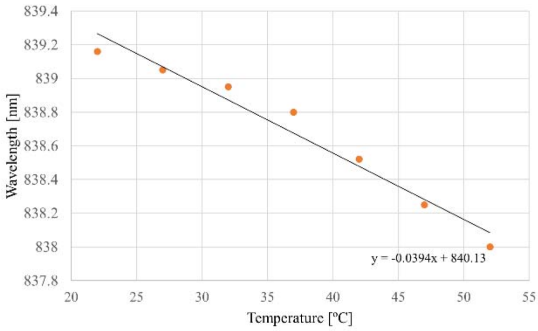

Fig. 4. Wavelength vs Temperature of the Bragg grating inscribed in 2-rings mPOF.

In order to characterize the strain sensitivity of the fabricated gratings, a 11.61 cm long fiber containing the grating was placed between two X-Y-Z stages fixed with flexure stage accessories (Thorlabs HFF001). The fiber was strained step-by-step while awaiting 5 min between each step at room temperature. As Figure 5 depicts, the computed strain sensitivity from a linear regression of the raw data was equal to 7.10±0.05 pm/με.The strain sensitivity of our results similar as three ring mPOF Bragg grating reported [10]

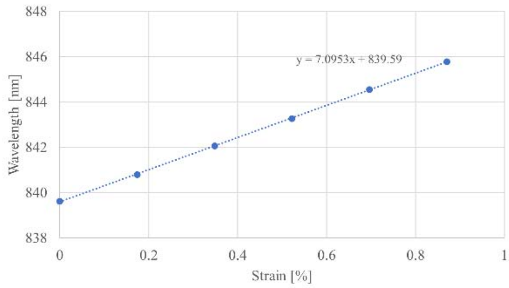

Fig. 5. Wavelength vs Strain of the Bragg grating inscribed in 2-rings mPOF.

Humidity experiment was carried out and the Bragg grating device was placed into a climate chamber (Angelantoni Industrie CH340) at a constant temperature of 22 ºC and 30% of relative humidity (RH) during 100 min for stabilization. Then the RH was increased up to a value of 90% in 20% step, waiting 100 min between each one. The reflected spectrum was monitored using an 850 nm circulator, a super luminescent diode (Superlum SLD-371-HP1) and an optical spectrum analyzer (Yokogawa AQ6373B). Figure 6 shows that the central wavelength shifts and humidity change with time, and the computed humidity sensitivity from a linear regression of the raw data was equal to 0.030 ±0.005 nm/%RH. The humidity sensitivity similar as step-index POF Bragg grating at 850 nm wavelength region [11].

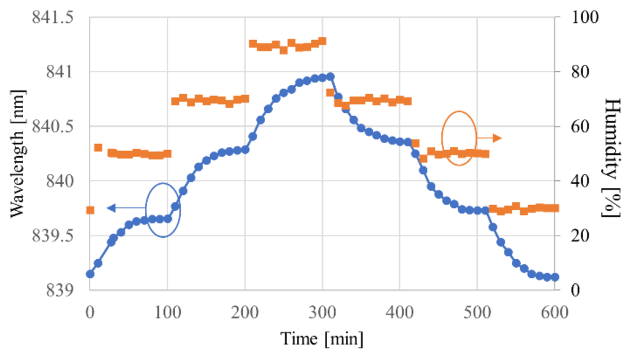

Fig. 6. Wavelength vs Humidity of the Bragg grating inscribed in 2-rings mPOF.

IV. Conclusion

In this work, we exploited two ring structure undoped PMMA mPOF containing an FBG inscribed at low loss 850 nm region with a relative low cost Nd:YAG laser operating at 266 nm wavelength. Temperature, strain and humidity tests were carried out and its sensitivities were computed. Combining the benefit of low loss undoped mPOF, low loss at 850 nm region and relative low price of 266 nm laser system, we can consider it as a milestone for potential commercial applications.

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References

[1] D. J. Webb, "Polymer fiber Bragg grating sensors and their applications," in Optical Fiber Sensors Advanced Techniques and Applications, G. Rajan Ed. Boca Raton, FL, USA: CRC Press, 257–276 (2015).

[2] Z. Xiong, G. D. Peng, B. Wu, P. L. Chu, (1999). Highly tunable Bragg gratings in single-mode polymer optical fibers. IEEE Photonics technology letters, 11(3), 352-354.

[3] D. Sáez-Rodríguez, K. Nielsen, H. K. Rasmussen, O. Bang, D.J Webb, (2013). Highly photosensitive polymethyl methacrylate microstructured polymer optical fiber with doped core. Optics Letters, 38(19), 3769-3772.

[4] J. Yu, X. Tao, H. Tam, (2004). Trans-4-stilbenemethanol-doped photosensitive polymer fibers and gratings. Optics letters, 29(2), 156-158.

[5] C. A. F. Marques, L. B. Bilro, N. J. Alberto, D. J. Webb, and R. N. Nogueira, Narrow bandwidth Bragg gratings imprinted in polymer optical fibers for different spectral windows, Opt. Commun. 307, 57–61 (2013).

[6] I-L. Bundalo, K. Nielsen, C. Markos, and O. Bang, "Bragg grating writing in PMMA microstructured polymer optical fibers in less than 7 minutes," Opt. Express 22(5), 5270–5276 (2014).

[7] R. Oliveira, L. Bilro, R. Nogueira, (2015). Bragg gratings in a few mode microstructured polymer optical fiber in less than 30 seconds. Optics express, 23(8), 10181-10187.

[8] L. Pereira, et al. Polymer optical fiber Bragg grating inscription with a single Nd: YAG laser pulse. Optics Express 26.14 (2018): 18096-18104.

[9] J. Janting, J. Pedersen, R. Inglev, G. Woyessa, K. Nielsen, O. Bang, (2019). Effects of Solvent Etching on PMMA Microstructured Optical Fiber Bragg Grating. Journal of Lightwave Technology. early access

[10] A. Pospori, C. A. F. Marques, D. Sáez-Rodríguez, K. Nielsen, O. Bang, D. J. Webb, (2017). Thermal and chemical treatment of polymer optical fiber Bragg grating sensors for enhanced mechanical sensitivity. Optical Fiber Technology, 36, 68-74.

[11] R.Min, B. Ortega, X. Hu, C. Broadway, C. Caucheteur, C. F. J. Pun, H-Y Tam, P. Antunes, C. Marques, (2018). Bragg gratings inscription in TS-doped PMMA POF by using 248-nm KrF pulses. IEEE Photonics Technology Letters, 30(18), 1609-1612.