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FBG inscription in CYTOP polymer optical fiber through over-clad using phase mask technique

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Abstract: A novel FBG inscription method in cyclic transparent fluoropolymer (CYTOP) polymer optical fiber through the over-clad using phase mask technique and a femtosecond (fs) pulsed laser at 400 nm is reported. It shows that 8 mm-long uniform grating is obtained in less than 20 s with 500 μW average beam power.

1. Introduction

Fiber Bragg grating (FBG) is a periodic modulation of the refractive index in the fiber core, which leads to a classical and efficient sensing method in optical fiber. Due to significant properties such as low Young's modulus, biocompatibility, low weight, and high flexibility, CYTOP polymer optical fibers received more and more attention in the fields of sensing applications [1]. Considering the FBG inscription methods in the CYTOP, to date two methods are mainly used, i.e., direct inscription (plane by plane or point by point) and phase mask technique. Direct inscription method [1] writes a grating with high reflectivity and low repeatability. Moreover, it needs expensive high precision automated translation stages. The second method uses a phase mask and a femtosecond laser, and was used recently with 400 nm femtosecond pulses to fabricate gratings in CYTOP without over-clad [2]. While gratings with high reflectivity and good repeatability were achieved, the fiber exhibits weaker mechanical properties as the over-clad is removed [2]. In this work, we extend the phase mask/femtosecond laser technique to through the over-clad inscription of gratings, preserving therefore the CYTOP fiber integrity and improving the grating repeatability.

2. Experimental set-up and results

The FBG inscription is performed with a femtosecond laser (Mai Tai and Spitfire Pro. amplifier from Spectra Physics) producing 120 fs light pulses at 800 nm with a repetition rate of 1 kHz and energy of 4 mJ. Gratings in CYTOP fibers are inscribed with the second harmonic generated pulses at 400 nm built in a nonlinear crystal starting from the 800 nm original pulses. Then, the beam is followed by a variable attenuator and an iris to adjust the beam power and diameter, respectively. Finally, the beam is focused onto the core of the CYTOP fiber through the phase mask by a plano-convex cylindrical lens with a focal length of 100 mm. The phase mask has a period of 1158 nm, and a powermeter is inserted between the lens and the iris to measure the effective power of the inscription beam. Importantly, a cover glass (from Corning) is put between the phase mask and the CYTOP fiber to protect the phase mask. An FBG interrogator (FS2200 from FiberSensing) with a spectral resolution of 1 pm and a spectral range from 1500 nm to 1600 nm is used to monitor FBG spectrum evolution in real time. A 3-D translation stage is used to connect the CYTOP fiber with a SMF pigtail which makes the link towards the interrogator. Moreover, a small drop of refractive index matching gel ($n = 1.4646$ at 589.3 nm) is used between the two optical fibers to reduce Fresnel reflections from the interfaces of the SMF and CYTOP [2]. The commercially available graded-index CYTOP fiber (GigaPOF-62SR from Chromis) is used in this fabrication, with core diameter, over-clad diameter, and numerical aperture of 62.5 μm, 490 μm, and 0.185, respectively [3].

Figures 1 (a) and (b) show a schematic view of the inscription system for the 62.5 μm core diameter CYTOP fibers and a picture of the experimental set-up, respectively. We fabricate a series of 8 mm-long FBGs in CYTOP fiber through the over-clad by varying the inscription beam power and the inscription time. The light intensity I is used to measure the amount of power per unit area that reaches the fiber core during the inscription neglecting the material absorption, and it is expressed by

$$I = \frac{\pi P}{4 \lambda F} \tag{1}$$

where P is the beam average power, λ is the inscription wavelength, and F is the focal length of the lens. As the focal length and the inscription wavelength are fixed to 100 mm and 400 nm respectively in this set-up, only

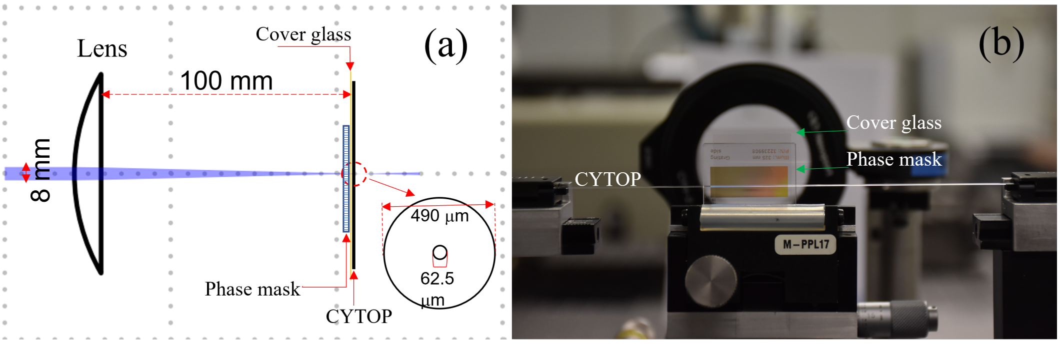

Fig. 1. CYTOP FBG fabrication set-up: (a) the schematic of 8 mm beam diameter light system to inscribe FBG in 62.5 µm core diameter CYTOP fibers with over-clad; (b) picture of the real setup.

the power *P* can be adjusted during the fabrication. When the power is less than 300 µW, no gating is found in the experimental spectrum, whereas the CYTOP fiber is damaged for power higher than 700 µW. The beam power was therefore restricted to the range 300 µW to 700 µW. Then for each power level, the reflection spectrum is monitored during inscription to stop it when the fundamental peak reaches its maximum value. This leads to inscription times in the range 7 s to 60 s.

Figure 2 presents three gratings with different beam powers and inscription times. The best spectrum, i.e., the one (grating #2) with the maximum fundamental peak reflection, occurs for a beam power of 500 µW with an inscription time of 20 s, which corresponds to a light intensity of 9.82×10^{-9} W/µm^2. In addition, the black dotted lines represents the theoretical resonance wavelengths of the first five mode groups. This computation is based on FBG in multimode fibers [2], and clearly demonstrate the quality of the grating.

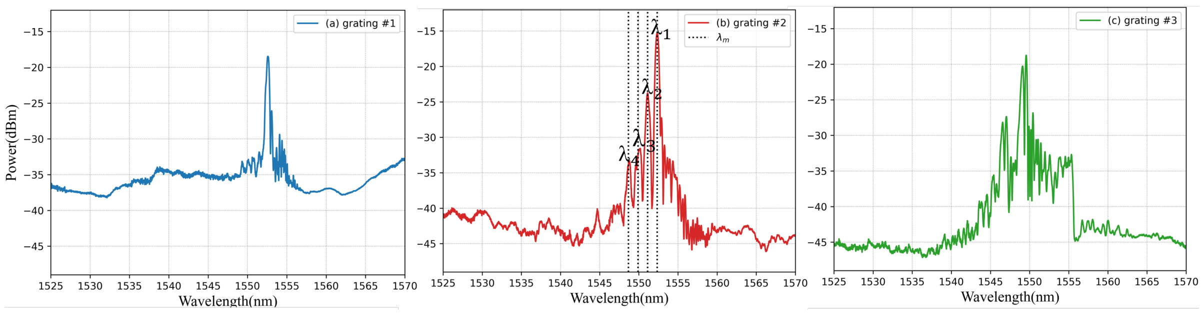

Fig. 2. Inscription parameters: a) grating #1 with laser power 400 µW, and inscription time 45 s; b) grating #2 with laser power 500 µW, and inscription time 20 s; and c) grating #3 with laser power 600 µW, and inscription time 10 s.

For a smaller power, longer time is needed, but the the main reflection peak is lower (grating #1, Fig. 2 (a)). On the other hand, with higher power, less time is needed, but the refection spectrum is strongly distorted (grating #3, Fig. 2 (c)).

3. Conclusion

We have successfully written FBGs in CYTOP fiber through the over-clad by using a femtosecond pulsed laser emitting at 400 nm and the phase mask technique. For a 8 mm-long grating, the reflection spectra shows the best performances when the average beam power and the exposure time are 500 µW and 20 s, respectively.

References

1. A. Theodosiou, A. Lacraz, A. Stassis, C. Koutsides, M. Komodromos, and K. Kalli, ”Plane-by-Plane Femtosecond Laser Inscription Method for Single-Peak Bragg Gratings in Multimode CYTOP Polymer Optical Fiber,” Journal of Lightwave Technology, vol. 35, no. 24, pp.5404 - 5410, Nov. 2017.
2. Y.-G. Nan, D. Kinet, K. Chah, I. Chapalo, C. Caucheteur, and P. Mégret, ”Ultra-fast fiber Bragg grating inscription in CYTOP polymer optical fibers using phase mask and 400 nm femtosecond laser,” Optics Express, vol. 29, no. 16, pp. 25824, Jul. 2021.
3. *Information on the detail of CYTOP GigaPOF62S*, https://fiberfin.com/custom/upload/File-1403278487.pdf.