Helical long-period grating on multicore fiber for refractive index sensing

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***Abstract*—We have fabricated and experimentally demonstrated a twisted multicore fiber for refractive index sensing. The overall refractive index response is nonlinear. The helical structured fiber achieved a high refractive index sensitivity of 1077 nm/RIU in the range of 1.418 to 1.444 RIU.**

***Keywords*—fiber optics sensors, microstructured fibers, refractive index**

I. Introduction

Refractive index (RI) sensing is essential in various fields such as biomedical, environmental monitoring and chemical engineering [1]. Owing to its advantages like small size, wavelength selectivity and immune to electromagnetic interference, fiber gratings sensors have attracted much attention. Unlike traditionally fiber Bragg grating, long-period grating (LPG) introduces losses at the cladding-air interface when light is guided from fundamental core mode to cladding modes, which is the resonance of the guided mode. Hence, the effective refractive index of the cladding depends on the refractive index of the surrounding medium. This makes LPG a good candidate for RI sensing. X. Shu *et al.* demonstrated a sampled fiber Bragg grating for refractive index sensing and achieved 294nm/RIU near RI of 1.42 [2]. However, a much higher sensitivity is needed for biomedical and chemical applications. Lately, Liao *et al.* have fabricated helical structured microfiber for SRI sensing purposes using femtosecond laser [3]. Modifications on optical fiber such as etching and tapering would enhance the sensitivity; on the other hand, these fibers became mechanically fragile. In the previous works, H. Zhang *et al.* have demonstrated twisted multicore fiber (MCF) for torsion and strain sensing [4, 5]. Twisted fibers showed relatively good mechanical strength. However, the length of the twisted region is too short to realize LPG.

In this work, we proposed to twist a MCF mechanically to form a helical structure. The helical structure has sufficient length to realized helical long-period grating (HLPG). We have experimentally demonstrated the highly sensitive HLPG RI sensor. Moreover, the HLPG has a larger free spectral range (FSR) between adjacent guiding modes, which allows a wider range of RI sensing.

II. Sensor Fabrication

The proposed HLPG was built on a MCF that has seven cores as shown in Fig.1 (a). The core and cladding diameters are 8.4 μm and 125 μm, respectively, and a pitch of 42 μm separates the cores. The trench surrounding each core is to reduce crosstalk between different cores. The twisting of MCF is done through deploying a CO_2 laser splicer (Fujikura, LZM-100). The rotating rotor of the splicer on the left-hand side had a rotation rate of 120°/ms while the right-hand side rotor was fixed. Both left and right moving motors had a speed of 0.1 μm/ms moving horizontally towards the

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direction of right. The twisted MCF has a period of 306.12 μm as shown in Fig.1 (b) and overall twisted length of 2.29 cm. Each end of the MCF was spliced with a single mode fiber (SMF).

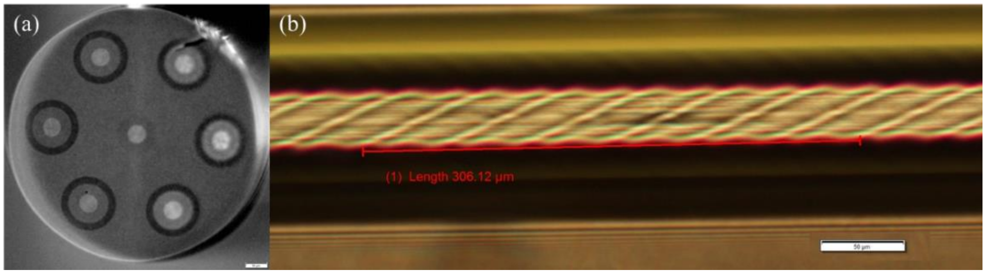

Fig.1. Microscope images of the twisted MCF (a) End view; (b) Side view

III. Sensor Characterization

In order to investigate the RI response of the sensor, the SMFs on both ends of the sensor were clamped on fixed stages to avoid any unnecessary variation of tensions and torsions, as the variations would cause resonance wavelength shift. The different RI solutions were prepared using different concentrations of glycerine by mixing it with water. The experiments were conducted in an order of increasing RI. Deionized water was used to remove excessive glycerine solution on the sensor between each test. The resonance dip has a blue shift with increasing RI as shown in Fig. 2 (a). The overall RI response of the proposed fiber is nonlinear as shown in Fig. 2 (b). The RI sensitivity was about 193 nm/RIU for the RIU range of 1.3328 to 1.4051; however, the sensitivity increased dramatically to 1077 nm/RIU for the RIU range of 1.4185 to 1.4447.

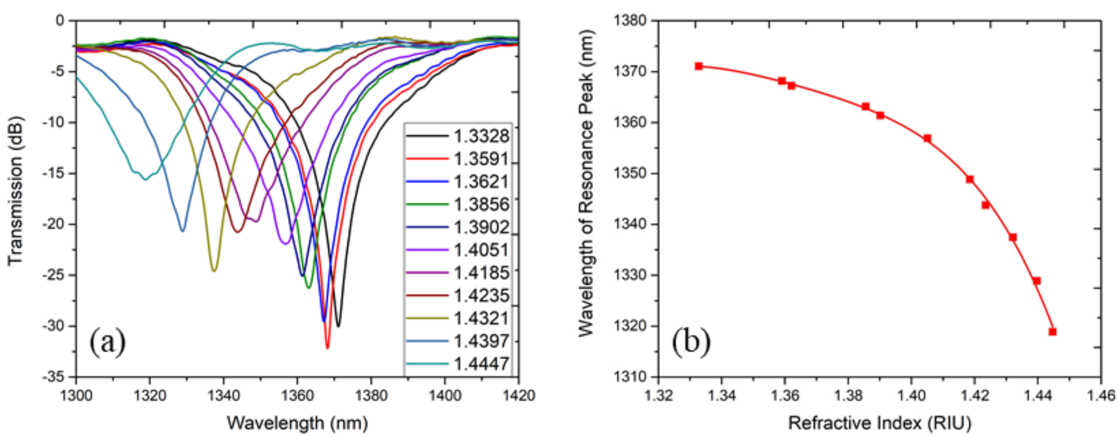

Fig.2. (a) Transmission spectra for serval refractive index values. (b) Refractive index response

IV. Conclusions

In this paper, we have fabricated and experimentally demonstrated a RI sensor based on HLPG MCF. Twisted fiber is mechanically stronger than other alterations on fiber. The proposed sensor exhibits a high RI sensitivity of 1077 nm/RIU for the RIU range of 1.418 to 1.444. Besides, the sensor could measure a large range of RI due to the large FSR between adjacent LP modes.

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