# Refractive Index Sensors Based on the Long Period Grating Inscribed in Tapered Few Mode Fiber

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***Abstract*—We proposed a high sensitivity refractive index sensor based on tapered few mode fiber long-period fiber gratings. The sensitivity of the sensor can be up to 4632nm/RIU.**

***Keywords—Tapered, Long-period fiber grating***

## I. INTRODUCTION

With the maturity of optical fiber preparation technology, long-period fiber gratings are widely used in optical fiber communication and optical fiber sensing due to the advantages of low cost, flexible design and mature preparation process. Long-period fiber gratings are affected by various parameters such as refractive index[1], temperature[2], strain[3], etc., and are manifested as the offset of resonant peaks in the transmission spectrum, and the sensing of corresponding parameters can be realized by measuring the change of resonance wavelength, which has attracted more and more attention in the field of optical fiber sensing.

Fan et al. used the arc discharge method to prepare LPFG on a tapered fiber with a diameter of 6.3µm, and the SRI sensitivity was up to 3762 nm/RIU[4].Fu et al. used the optical fiber splicer to pull the FM-LPFG to prepare a high-sensitivity tapered FM-LPFG temperature sensor, when the temperature is in the range of 30 °C ~ 90 °C, the temperature sensitivity of the sensor can reach 0.0393nm/°C[5].Liu et al. proposed a novel tapered two-mode fiber embedded long-period fiber grating (TTMF-LPFG) sensor, when the taper waist diameter is 36 µm, the maximum SRI sensitivity reaches 1360.43 nm/RIU[6].

In this work, We prepared long-period fiber gratings of tapered few-mode fiber. The influence of different taper waist diameters on the refractive index sensitivity was investigated. Such a high sensitivity refractive index sensor has a potential application in many fields.

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## II. THEORTICAL ANALYSIS AND FABRICATION

### A. Theoretical Analysis

In the experiment, the fiber used is a step-index FMF(YOFC)[7].The FMF has a core diameter of 16µm, a cladding diameter of 125µm, and the RI difference between the cladding and core of fiber is 0.01.

On the basic of the coupled mode theory, the phase matching condition of LPFG is given by[8]

$$\lambda_{res} = (n_{eff,co} - n_{eff,cl})\ \Lambda \tag{1}$$

where, $\lambda_{res}$ is the resonance wavelength, $n_{eff,co}$ and $n_{eff,cl}$ represent the effective RI of the core mode and cladding mode, respectively, $\Lambda$ represents the LPFG period.

### B. Fabrication

In the experiment, the preparation of long-period fiber gratings of tapered few mode fiber was divided into two steps, firstly, the carbon dioxide-laser glass-processing system(AFL Fujikura,LZM-100) was used as the heating source to prepare the tapered fiber, and then LPFGs was prepared on the fiber after tapered.

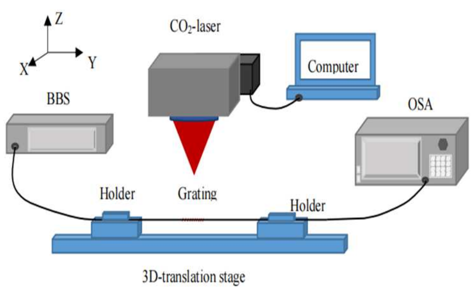


Fig. 1 Schematic diagram of the experimental setup

The LPFGs were fabricated by a $CO_2$ laser ($CO_2$-H10, Han's Laser) through point by point inscription in the FMF. The average power and the pulse frequency of the $CO_2$ laser were 0.6W and 5kHZ, respectively. The schematic diagram of the experimental setup for the LPFG fabrication is shown in Fig. 1. Both ends of FMF were spliced with single-mode fibers (SMFs). The focused laser beam scanned the fiber along the fiber axis. The laser scanned processes may be repeated for several cycles until a LPFG with high spectral contrast was formed. Light from a supercontinuum broadband light source (NKT Photonics) was launched into the FMF , and the transmission spectra of the gratings were monitored by an optical spectrum analyzer (OSA, AQ6370D, YOKOGA WA).

## III. EXPERIMENTAL RESULT AND DISCUSSION

### *A. Fabrication of LPFG with Different Diameters*

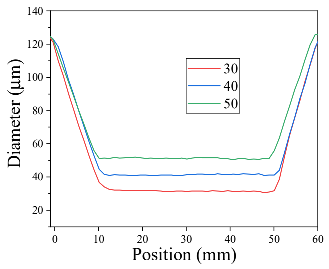


Fig. 2 Changes in the diameter of the taper region of the tapered FMF, the diameters of the taper waists are: 50-30μm

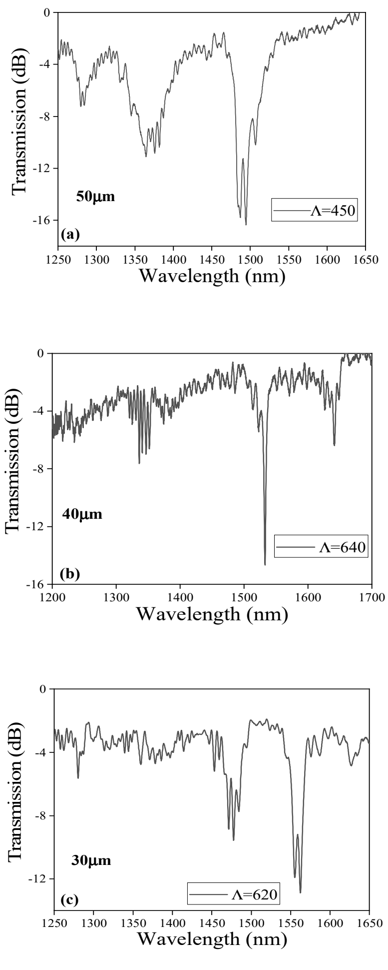


Fig. 3 Transmission spectrum of FMF at different diameters

The system testing software is used to drive the built-in image processing system of the fusion splicer to scan the surface of the fiber with a resolution of 0.2 mm/s to measure the diameter change of the prepared tapered FMF. Fig. 2 shows the diameter changes of the tapered FMF with a taper waist diameter of 50-30μm, and the lengths of each taper region are 1, 4, and 1 cm, respectively.

We fabricated long-period fiber gratings on few-mode fiber of 50-30μm, respectively. Fig. 3(a) shows the LPFG prepared on a fiber diameter of 50μm with period of 450um and the resonant wavelength is 1493nm. Fig. 3(b) shows the LPFG prepared on a fiber diameter of 40μm. The period of the TMF-LPFG in our experiment is 640um, the resonant wavelength is 1532.6nm. As shown in Fig.3(c), we fabricated LPFG on the fiber diameter of 30μm with period of 620μm, the resonant wavelength is 1550nm.

### *B. SRI Sensing Characteristics of Tapered FMF-LPFG*

The refractive index characteristics of 50μm FMF-LPFG in the range of 1.333 to 1.454 were investigated. As shown in Fig.4(a), (b), when the refractive index increased, the resonance wavelength was shifted to shorter wavelength, the resonant wavelength shifted 14 nm to short wavelength, the maximum surrounding refractive index sensitivity were measured to be -320nm/RIU.

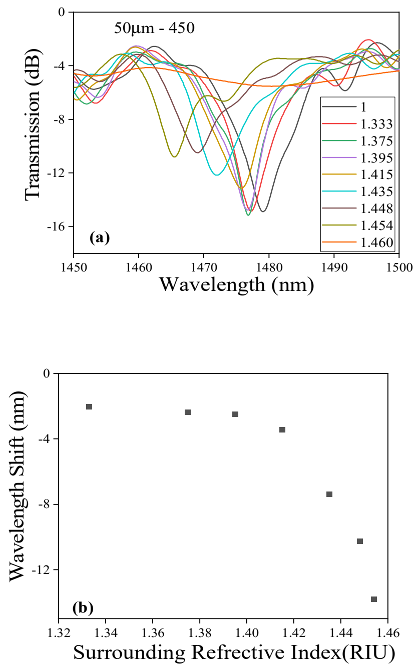


Fig. 4 Refractive index sensing characteristics of 50μm diameter FMF-LPFG

Fig. 5 shows the refractive index characteristics of 40μm FMF-LPFG in the range of 1.333 to 1.448, the resonant wavelength shifted 30 nm to short wavelength, the maximum refractive index sensitivity increased to -4233nm/RIU.

Fig. 6 shows the refractive index characteristics of LPFG prepared on 30um FMF. In the refractive index range of 1.333 to 1.451, the resonant wavelength shifted 97 nm to the short wavelength, and the maximum refractive index sensitivity was -4632nm/RIU.

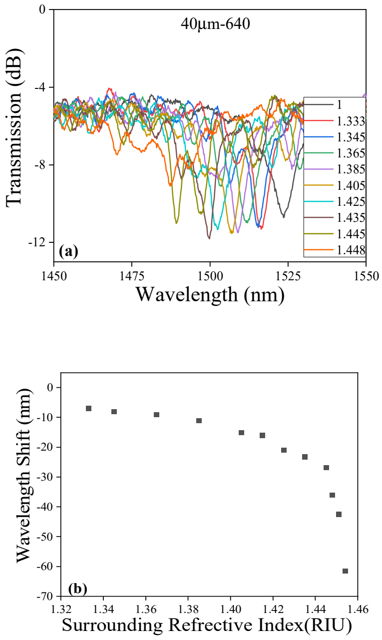


Fig. 5 Refractive index sensing characteristics of 40μm diameter FMF-LPFG

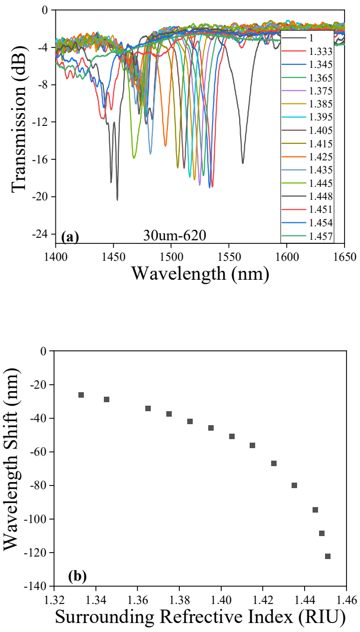


Fig. 6 Refractive index sensing characteristics of 30μm diameter FMF-LPFG

We compared the surrounding refractive index sensitivity of LPFGs prepared on optical fibers of different diameters, and through the experimental results, it can be found that under the influence of the same refractive index, as the diameter of the fiber decreases, the evanescent field inside the fiber increases, the resonance peak has a larger wavelength shift to the short wavelength, and the surrounding refractive index sensitivity is higher.

## IV. Conclusion

In conclusion, we fabricated a tapered FMF refractive index sensor using carbon dioxide laser processing system. We investigated the SRI characteristics of the tapered FMF-LPFG experimentally, the maximum SRI sensitivity was 4632 nm/RIU in an SRI range from 1.435 to 1.451. As the fiber diameter decreases, the evanescent field inside the fiber increases, The refractive index sensitivity of the fiber will also increase. The proposed sensor based tapered FMF-LPFG has a promising application as a high sensitivity SRI sensor.

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