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Realization of 1-D Diffraction Grating on the End Surface of Hollow Optical Fiber

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Abstract

We fabricated 1-D diffraction grating on the end surface of cleaved hollow optical fibers with a direct inscribing method using femtosecond laser pulses. The measured near and far fields were modulated by diffraction grating.

1 Introduction

Diffraction pattern can be observed in nature and also be obtained by an artificial repetitive array such as diffraction grating.[1] Propagation properties of light can be effectively controlled using diffractive optical elements as well as refractive elements such as lenses. Combination of diffractive optics and guided wave optics can provide versatile control of electromagnectic wave, and in recent years, especially, there have been various efforts to inscribe an index modulation pattern on the end surface of optical fiber.[2]

One of the methods is the surface relief grating using azo-polymer film, where the actual mass of layer is modulated.[3] Another approach is the direct inscribing microstructures on fiber surface using femtosecond laser pulses. Formation of these photorefractive index modulation structures can provide effective diffraction grating even on very tiny region with ultra high accuracy.[4,5]

In this study, we inscribed 1-D diffraction grating on the surface of cleaved hollow optical fiber (HOF) using a femtosecond laser. An unique ring-shaped beam of HOF with modulated grating experimentally demonstrated a potential for optical beam shaping in the visible range, which was not possible in conventional solid core single mode fiber (SMF).

2 Experiment

The experimental setup for diffraction pattern fabrication is schematically described in Fig. 1. Femtosecond laser pulses of 184 fs duration and 450μW power were generated with Ti-Sapphire laser with 785.5nm wavelength for inscription of 1-D grove arrays on the HOF surface. Focused beam with help of ×50 objective lens which had N.A 0.42 inscribed 1-D diffraction pattern as it moved horizontally. The period of the grating was 2 μm and the thickness of etched line was less than 1 μm.

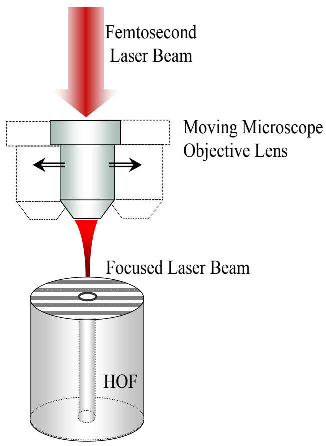
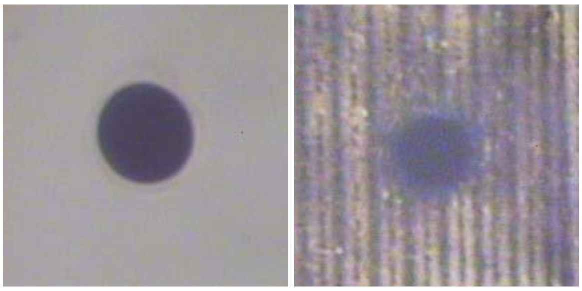


Fig.1. The schematic diagram of the experimental setup for fabrication of diffraction grating.

The actual cross-section images of the HOF before and after inscription are shown in Fig. 2. The dark line region indicates etched line by focusing femtosecond laser and the dark circle in the center is air-hole of the HOF which diameter was 10μm.

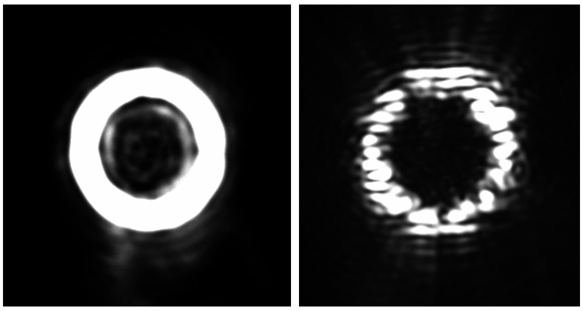
With the grating on the surface of HOF, the near field diffraction beam patterns shown in Fig.3 and 4 were measured by a charge-coupled device (CCD) with a He-Ne laser source of 635nm wavelength and a white light source.



(a) (b)

Fig.2. The real images of the surface of HOF; (a) before inscription, and (b) after inscription.

The figure 3-(a)/(b) shows the ring-shaped near field images of HOF without / with surface grating modulation, respectively. The effects of the grating were clearly shown in Fig. 3(b) with dark lines modulated on a ring-shaped beam.



(a) (b)

Fig. 3. The measured near-field images of HOF (a) without grating and (b) with grating. The source was 635nm He-Ne laser.

The figure 4 shows the far-field image of modulated HOF with white light and He-Ne laser sources. The zero'th and the first order are observed in both figures. It is interesting to note that the diffraction patterns strongly depended on the wavelength and the blue light was conspicuously diffracted in a Gaussian type as shown in Fig 4(a). To investigate the monochromatic diffraction pattern, we used 635nm He-Ne laser. As shown in Fig. 4(b), the pattern denotes somewhat complexity mainly caused by two factors, grating and ring-shaped HOF. The grating affected the separation of 0^{th} and 1^{st} order lobes and the ring-shaped HOF resulted in the shape of a lobe.

Not only the surface grating but also a unique beam shape of specialty optical fiber gives a new freedom of diffraction patterns design. The authors are in the process of investigating various core-shape of optical fiber with 1-D and 2-D surface modulation.

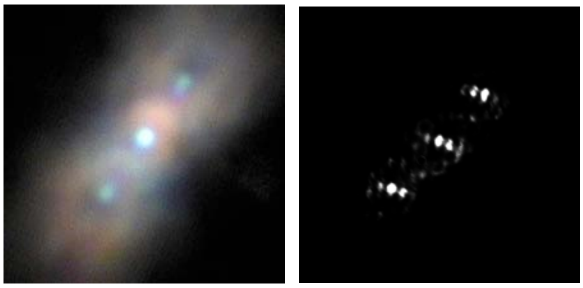


Fig. 4. Measured diffraction pattern; (a) with the white source and (b) with the laser source.

In conclusion, we fabricated one-dimensional surface grating on the end surface of HOF and verified the zeroth and the first order diffraction pattern. Furthermore, the compositive effect of grating and ring-shape core generated more complicated pattern compared to the case of Single Mode Fiber (SMF).

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