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Broadband Long Period Grating on Hollow Optical Fiber with Femtosecond Laser Pulses

W. Ha[1], Y. Jung[2], J. Kim[2], W. Shin[3], I. Sohn[3], D. Ko[3], J. Lee[3], and K. Oh[1]

[1] Institute of Physics and Applied Physics, Yonsei University 134 Shinchon-dong, Seodaemun-gu, Seoul 120-749, Republic of Korea,
Tel: 82-2-2123-5608, Fax: 82-2-392-1592, E-mail: koh@yonsei.ac.kr

[2] Department of Information and Communications, GIST 1 Oryong-dong, Buk-gu, Gwangju, 500-712, Republic of Korea

[3] Advanced Photonics Research Institute, GIST 1 Oryong-dong, Buk-gu, Gwangju 500-712, Republic of Korea

Abstract

We have fabricated a broadband long period grating on hollow optical fiber by using femtosecond laser pulses. The filter showed a low insertion loss of 1.7 dB and very broad FWHM of 160 nm.

1 Introduction

In order to accommodate flexible wavelength manipulation in WDM optical communication systems, passive and dynamic channel selective all-fiber filters are in great demand [1]. In recent years, all-fiber band rejection filter with extremely narrow bandwidth less than 0.8 nm and broad bandwidth over 100 nm filters have been investigated with various optical fibers and fabrication schemes.

Recently, authors have reported efficient and broad-band mode conversion in a hollow optical fiber (HOF), where the spectral bandwidth was over 160 nm [1, 2]. Broadband coupling has been attributed to unique mode-beating dispersion in HOF, which is composed of central air-hole, ring core, and cladding. The coupling strength, however, was limited in the previous report due to weak acousto-optic interaction and subsequent index modulation.

In this paper we tried to fabricate long period grating (LPG) on HOF by using femtosecond laser pulses to mechanically inscribe slots in order to obtain even stronger mode coupling and wide bandwidth. We report detailed fabrication process and transmission characteristics were thoroughly investigated.

2 Experiment

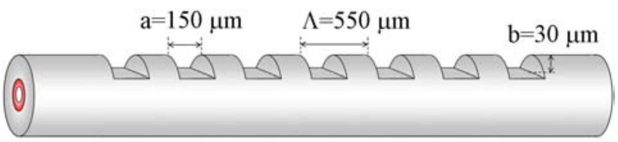

Fig.1. Schematic diagram of the LPG on HOF.

The proposed LPG structure is schematically illustrated in Fig.1. The cladding of HOF is corrugated by femtosecond laser irradiation to the appropriate dimensions. The HOF used in this experiment had dimensions of 6 μm air-hole diameter and an outer diameter of 125 μm [2].

Performance of the Ti:sapphire laser used in this experiment is given follow; wavelength of 785.5 nm, pulse duration of 184 fs, 1 kHz repetition rate, average power of 3.59 mW, and N.A. value of 0.42 with x50 objective lens. A one-meter-long HOF was carved by point-by-point exposure; width of 150 μm, depth of 30 μm, and period of 550 μm with 20 repeat times.

Because pristine HOF is sensitive to mechanical stress, the corrugated sample was found to be highly sensitive against mechanical bends. Fabricated HOF-LPG pictures are shown in Fig.2 and Fig.3, where corrugation structures are clearly shown. The surface roughness depends on laser power and irradiation time.

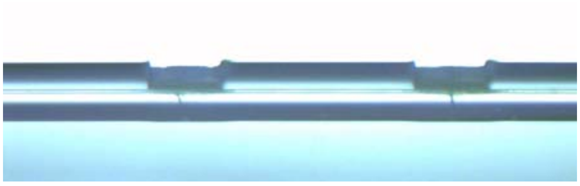

Fig.2. Side-view of the sample (a=150.45 μm, b=30.09 μm).

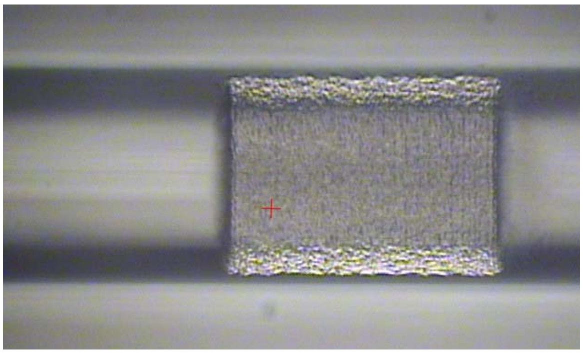

Fig.3. Top-view of the sample (a=150.45 μm, b=30.09 μm).

For the fabricated HOF-LPGs, we have experimentally measured the output transmission as a function of wavelength with a white light source and optical spectrum analyzer, as shown in Fig.4. Note that the HOF-LPG was placed in a straight fiber holder without any bending while the spectrum was measured, in order to eliminate any bending effect. The filter showed an insertion loss of 1.7 dB and FWHM of 160 nm in the wavelength range of 1630 nm. Coupling strength more than 8 dB was achieved for the band rejection peaks generated in the wavelength range shown in Fig.4. Note that this coupling efficiency is more than 3 dB enhancement compared with prior acousto-optic tunable filter (AOTF) [3].

Generally, LPGs based on conventional single mode fiber (SMF) provide band rejection in a spectral bandwidth about 10 nm. On the while in the HOF, the central air-hole and the ring core result in significantly different mode beating dispersion between the core mode guide along the ring structure and the cladding modes. As experimentally observed in the case of AOTFs [3], the phase matching condition for the LP_{01}^{core}-LP_{1m}^{clad} anti-symmetric mode coupling occurs in a broad spectral range, so that HOF-AOTF can provide much broader band of rejection than SMF.

In this experiment of HOF-LPG, we are interested in symmetric coupling, LP_{01}^{core}-LP_{0m}^{clad}, to confirm the broadband nature of HOF mode coupling. As we could observe in Fig.4, very wide band rejection was confirmed for LP_{01}^{core}-LP_{0m}^{clad}, as well, which shows good agreement with a prior report.

Note that surface roughness and flatness affect the transmission with the spectral noise due to modal interference.

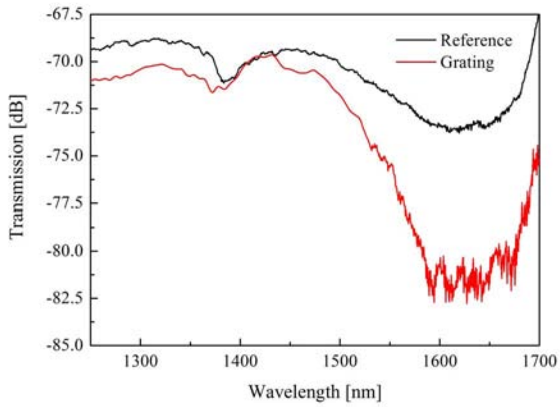

Fig.4. Transmission spectra as a function of wavelength.

In conclusion, we successfully fabricated a broadband (~ 160 nm) LPG on HOF by using femtosecond laser pulses. The filter showed an insertion loss of 1.7 dB and coupling strength of 8 dB.

3 Acknowledgement

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4 References

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