OPTOELECTRONICS AND ADVANCED MATERIALS – RAPID COMMUNICATIONS Vol. 11, No. 5-6, May-June 2017, p. 289 - 291

Fabrication of phase-shifted long-period fibre grating using electric-arc technique

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We propose and experimentally demonstrate the fabrication of long period gratings on the SMF using the electric-arc technique. By monitoring the transmission spectrum of the LPG, a deep notch over 16 dB was achieved within the operation wavelength band. Exploiting the point by point inscription method, π-phase-shift LPFG was achieved with a bandpass centered within two big notches. The proposed method has many advantages such as compact structure, cost-effective.

(Received May 04, 2016; accepted June 7, 2017)

Keywords: Long-period grating, Fiber, Phase-shift

1. Introduction

Due to their importance, long-period fibre gratings (LPFGs) have attracted much interest during the past few years. These in-fibre passive components are principally devoted to wavelength filtering and they were used some time ago to flatten the gain of erbium-doped fibre amplifiers (EDFAs) [1-2]. The coupling from the core mode to cladding modes offer a very wide field of application in areas such as fibre-optic communication and instrumentation and they are used as band rejection and tunable filters [3-4], as well as chromatic dispersion compensators [5]. They are also used as fibre-optic sensors for temperature and strain detection [6-7].

LPFGs are classically realized by exposing the optical fibre to ultra-violet (UV) laser, through an amplitude mask [1]. Beforehand, the fibre is hydrogen loaded in order to increase the photosensitivity and facilitate the refractive index change. Recently, gratings have been written by laterally submitting the fibre to either a CO_2 laser [8-10], or to an electric discharge [11]. The discharge can be performed in a standard non-hydrogenated fibre [12-14] or in pure silica-core fibre [15]. Periodic deformations of the fibre can be created by a CO_2 laser source [16], or an electric discharge [17].

The inscription mechanisms, such as physical deformations, stress relaxation or dopants diffusion, depend on the type of fibre used and its maintaining conditions (tension, bending). The nature of fibre perturbations induced by electric discharge is not well established. Thermal characterizations are performed to quantify the sensitivity of the gratings. Raman spectroscopy can be performed to identify any structural change in the fibre. An increase in fictive temperature is expected, this can be associated with an increase in density and refractive index. Raman spectra should show modifications of 490 and 650 cm^{-1} peaks.

In this work, we demonstrate the efficiency of a point to point grating inscription by exploiting the flexibility of the electric-arc technique, and also introduce π-phase-shifts into LPFGs. We also report the fabrication of bandpass filters with a high isolation of the two lateral rejection bands.

2. Principle and experimental setup

The LPFG period is typically a few hundred micrometers. The symmetry of the excited cladding modes depends on factors such as the fibre type and the grating fabrication parameters [18]. Normally, if we assume uniform cylindrical perturbations, light power is coupled from the core mode LP_{01} to the cladding mode LP_{0m}. The fiber jacket absorbs, over a few centimeters, almost the entire light power propagated by the cladding modes. This coupling occurs at a resonance wavelength λp given by the phase matching condition $\lambda_p = (n_{eff01} - n_{eff0m})\Lambda$, where $neff_{01}$ and $neff_{0m}$ are respectively, the effective index of the core fundamental mode and the cladding modes, Λ is the grating period. The power transfer to a cladding mode at λ_p is given by $T = \sin^2(C_m L)$, L is the length of the grating and C_m the coupling coefficient. The complete power transfer is obtained when the condition $C_m L=\pi/2$ is satisfied. We can easily obtain the approximate expression for the full-width at half maximum (FWHW) Δλ. The width diminishes as the grating length increases. The characteristics of the transmitted spectrum depend on the period Λ, the refractive index change induced by the electric arc, the grating length and the maintaining conditions of the fibre.

The electric-arc technique is simple and easy to handle. The experimental setup consists in submitting the fibre to electric discharges provided by a commercial splicer (Ericsson FSU 995). A translation stage displaces the fibre, after each discharge, by a distance that represents the grating period (Λ). As the grating is being written, the evolution of the transmitted spectrum is monitored using an optical spectrum analyzer (OSA) and a broadband light source. This technique allows the inscription of the grating without the need of hydrogen-loading or Ge-doped core fibres [19].

Since this grating is written period after period, the introduction of any phase-shift is simply performed by translating the fibre after a distance L_p equivalent to the required phase-shift: $\Delta\phi = 2\pi L_p/\Lambda$. The grating inscription is then continued until the passband is obtained, when the total grating length is reached. Therefore, this technique is more flexible than the UV technique since it does not require the fabrication of a specific amplitude mask for each desired resonance wavelength and phase-shift value.

3. Experiment results and discussion

Fig. 1 shows the measured transmission spectrum of the LPFG fabricated on a segment of normal SMF28 fiber. The grating period was chosen to be 500 µm, and the electric arc steps we used was around 50, which gives the grating over 50 periods.

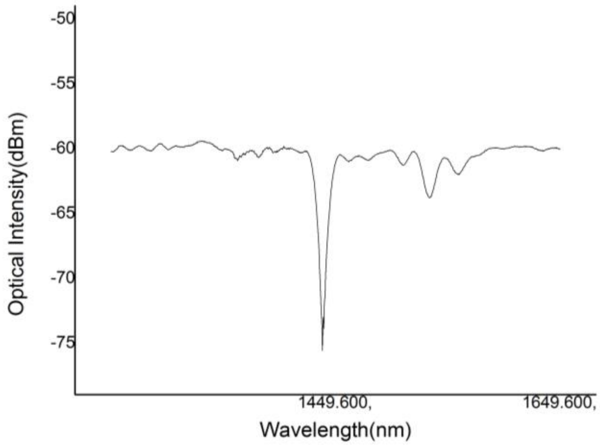
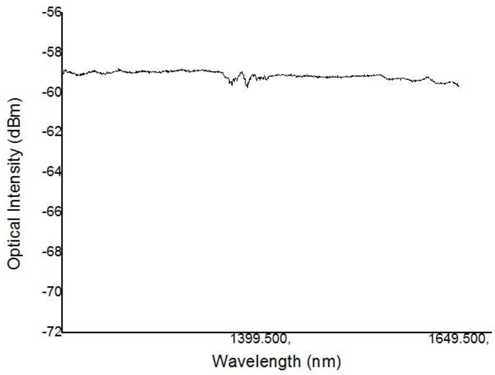


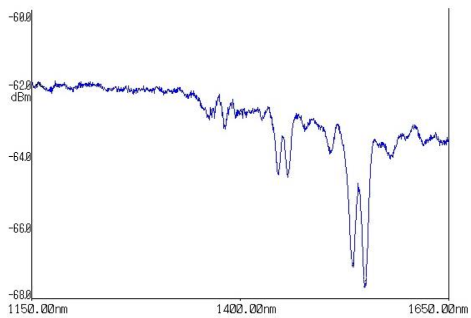
Fig. 1. Experimental result of the transmission spectrum of the LPFG fabricated on the single mode fiber (SMF) monitored with an OSA

The splicer's parameter was chosen as follow: the electric arc current is 10 mA and the exposure time of 1 s, in order to get the best performance. As can be seen from Fig. 1, the grating has a notch centered at 1438.4 nm with a depth of over 16 dB. The blue line with the figure was the transmission spectrum before the fabrication of the grating, and the green line is the grating spectrum after 50 fabrication steps.

Fig. 2 shows the experimental results of the π-phase-shifted LPFG fabricated using the electric-arc technique. Fig. 2(a) is the measured transmission spectrum of the SMF before the grating fabrication. And Fig. 2(b) shows the transmission spectrum of the π-phase-shifted LPFG after 60 steps. The grating period is 600 µm, and the electric arc current is 10 mA and the exposure time of 1 s. The phase shift distance L_p is 300 µm, which generates a π phase shift at the centre of the grating length. The unevenness of the two peaks centered at 1534 nm and 1549 nm in Fig. 2(b) was due to the imperfect of the fabrication conditions, such as the symmetry of the excited cladding modes, the imperfect alignment of the fibre, inappropriate location of the phase shift applied to the fibre, uneven distribution of the electric arc at the heating points, unwanted strain or tension applied to the fibre and the temperature changes of the experimental environment [20]. It is worth noting that we can easily apply any phase-shift value by just change the distance L_p during the grating inscription process. Also, we can apply the desired phase-shift value at any position of the grating, since the grating is written in a period after period manner.



(a)



(b)

Fig. 2. (a) The measured transmission spectrum of the SMF before the grating fabrication; (b) The measured transmission spectrum of the SMF after the fabrication of the phase-shifted LPFG

4. Conclusion

We proposed and experimentally demonstrated the fabrication of LPGs on the SMF using the electric-arc technique. By monitoring the transmission spectrum of the LPG, a notch spectrum with a depth over 16 dB was achieved within the operating wavelength band. Exploiting the point by point inscription method, π-phase-shift LPFG was achieved with a bandpass centered between two big notches. The proposed method has many advantages such as compact structure, cost-effective.

Acknowledgment

This work was financially supported by the China Scholarship Council under grant no. 201308420605 and the Hubei University of Technology's Doctoral start-up fund under grant no. 337, 144.

References

[1] A. M. Vensarkar, J. R. Pedrazzani, J. B. Judkins, P. J. Lemaire, Opt. Lett. **21**(5), 336 (1996).
[2] P. F. Wysocki, J. B. Judkins, R. P. Espindola, M. Andrejco, A. M. Vengsarkar, IEEE Photonics Technology Letters **9**(10), 1343 (1997).
[3] A. M. Vengsarkar, P. J. Lemaire, J. B. Judkins, V. Bhatia, T. Erdogan, J. E. Sipe, J. Lightwave Technol. **14**(1), 58 (1996).
[4] O. Duhem, A. DaCosta, J. F. Hennino, M. Douay, Electron. Lett. **35**(12), 1014 (1999).
[5] M. Das, K. Thyagarajan, Photonics **1**, 303 (2000).
[6] V. Bathia, A. M. Vengsarkar, Opt. Lett. **21**(9), 692 (1996).
[7] B. H. Lee, J. Nishi, Electron. Lett. **34**(21), 2059 (1998).
[8] D. D. Davis, T. K. Gaylord, E. N. Glytsis, S. G. Kosinski, S. C. Mettler, Electron. Lett. **34**(14), 1416 (1998).
[9] D. D. Davis, T. K. Gaylord, E. N. Glytsis, S. G. Kosinski, S. C. Mettler, A. M. Vengsarkar, Electron. Lett. **34**(3), 302 (1998).
[10] S. Yamasaki, M. Akiyama, K. Nishide, A. Wada, R. Yamauchi, IEICE Trans. Electron. E **83**(3), 440 (2000).
[11] G. Humbert, A. Malki, Electron. Lett. **39**(21), 1506 (2003).
[12] S. G. Kosinski, A. M. Vengsarkar, OFC'98 Technical Digest 278, (1998).
[13] N. Goodbout, X. Daxhelet, A. Maurier, S. Lacroix, ECOC'98 397, (1998).
[14] E. M. Dianov, V. I. Karpov, A. S. Kurkov, M. V. Grekov, ECOC'98 395, (1998).
[15] T. Enomoto, M. Shigehara, S. Ishikawa, T. Danzuka, H. Kanamori, OFC'98 Technical Digest 277, (1998).
[16] C. D. Poole, H. M. Presby, J. P. Meester, Electron. Lett. **30**(17), 1437 (1994).
[17] I. K. Hwang, S. H. Yun, B. Y. Kim, Opt. Lett. **24**(18), 1263 (1999).
[18] G. Rego, O. V. Ivanov, P. V. S. Marques, Opt. Express **14**(21), 9594 (2006).
[19] G. Humbert, A. Malki, S. Février, P. Roy, D. Pagnoux, Electron. Lett. **39**(4), 349 (2003).
[20] A. Martinez-Rios, I. Torres-Gomez, G. Anzueto-Sanchez, R. Selvas-Aguilar, V. M. Duran-Ramirez, J. A. Guerrero-Viramontes, D. Toral-Acosta, G. S. Delgado, A. Castillo-Guzman, Opt. Commun. **64,** 37 (2016).

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