Optics & Laser Technology 44 (2012) 1176–1179

Contents lists available at SciVerse ScienceDirect

Optics & Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Research Note

Random period arc-induced long-period fiber gratings

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ARTICLE INFO

Article history:
Received 6 September 2011
Received in revised form
22 November 2011
Accepted 23 November 2011
Available online 7 December 2011

Keywords:
Long-period fiber gratings
Random period
Refractive index

ABSTRACT

We report the fabrication of arc-induced long-period fiber gratings with strong random variations in the period. Long-period fiber gratings with standard deviations in the period from 8.50 to 36.98 μm were fabricated. The spectral position of the resonant bands is determined by the average period value, being similar to that observed in a long-period fiber grating with a fixed period equal to the average period of the random grating. Moreover the notch bands keep the shape characteristics like wideband and depth compared with a long-period grating with a constant period. In addition, their sensitivity to external parameters such as ambient refractive index is not too different with that of fixed period long-period gratings.

1. Introduction

Long-period fiber gratings (LPFGs) are devices where the coupling between co-propagating core and cladding modes results in the formation of well defined loss bands at wavelengths determined by the period of the grating and the fiber characteristics [1]. LPFGs can be fabricated in optical fibers by the application of a periodic perturbation of the refractive index, which can be induced by UV [2] or CO_2 [3] laser irradiation, by the application of mechanical stress [4], by the application of an electric arc [5], or even using an UV lamp [6]. An important factor to note is that in the case of LPFGs fabricated by laser irradiation the affected zone where the refractive index is perturbed is of a few microns in the case of UV irradiated fibers and maybe less than 50 μm for CO_2 laser irradiation, while for arc-induced LPFGs the affected zone is higher than 300 μm. Thus, in the first two cases even small variations in the period may significantly affect their transmission characteristics. In Ref. [7], the effect of slight random variations in amplitude and period during the grating fabrication were simulated, finding that random period variations degrade the spectral characteristics of the gratings. On the other hand, in Ref. [8] a nonuniform LPFG was numerically designed to provide a linear sensitivity curve to external refractive index. In this case, the grating period has a cosine-like period variation, with ~3 μm variation range (i.e. the difference between the maximum and minimum period). In contrast, the perturbation zone in arc-induced LPFGs has a gradient along the longitudinal and transverse directions that may vary from point to point and affects their reproducibility under the same assumed fabrication conditions, particularly in poorly aligned setups [9]. In the size of the affected zone and its gradient along the longitudinal and transverse directions we may see arc-induced LPFGs having a random chirp, which make its reproducibility difficult unless special measures are taken during the fabrication [10].

In this work, we present the formation of LPFGs with random variation ranges up to 125 μm (standard deviation of 36.98 μm) in dispersion-shifted fiber (DSF) fabricated by the electric arc method. We found that the position of the resonance peaks is approximately determined by the mean period, i.e., the number and position of the resonances correspond to that obtained with a fixed period grating with period close to the mean value. Moreover, the spectral characteristics does not degrade, for example, the FWHM spectral width is not different from that obtained with fixed period LPFGs and in some cases is slightly smaller. Furthermore, we have measured the response to changes in external refractive index of the random period LPFGs without finding any significant difference in the response curve with the dispersion in the random period.

2. Experimental setup

Fig. 1 shows a sketch of the experimental setup used for the fabrication of the arc-induced LPFGs. The fiber holders, V-groves, and electrodes are contained within a commercial fusion splicer S-176 from Fitel. One of the fiber holders (the right holder in

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doi:10.1016/j.optlastec.2011.11.037

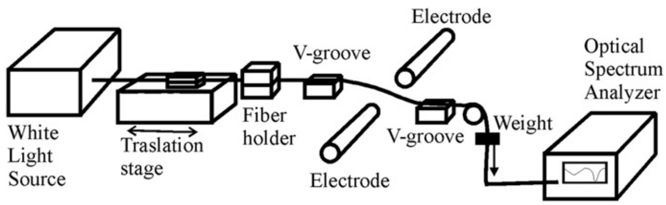

Fig. 1. Experimental setup used for the fabrication of the random period gratings.

Fig. 1) was removed from the fusion splicer and the V-grooves were displaced from its aligned position in manual mode to enhance the asymmetry of the electric arc gradient in all directions. On the side where the fiber holder was removed, there is a pulley through which the fiber slides while it is kept under tension by a dead weight. At each discharge the left fiber holder is closed keeping the fiber in position, while the V-groves determine the position of the fiber with respect to the electrodes, and the pulley and weight allow the application of a controlled tension during the LPFG inscription. When the translation stage controlled by a step motor is moved to the next position the fiber holder is released and the fiber advances by itself to the next point due to the applied tension. The arc power for each discharge was kept at 10 mW, with an arc duration of 200 ms. It is worth to note that the lowest allowed values of arc power and arc duration for this particular fusion splicer is 5 mW and 100 ms, while a typical power for a fusion splice is >60 mW and >800 ms. Here, we only concentrate in fabricating LPFGs in dispersion-shifted fiber (DSF). To choose the random period, in other words the random chirp of the LPFG, we used random number generator (60 numbers or 60 periods in all cases) corresponding to the "steps" of the step-motor. For our particular setup each step of the motor corresponds to an advance of approximately 1.25 μm of the translation stage, i.e., 400 steps correspond to 500 μm of linear advance. The LPFG thus fabricated were monitored continuously during the inscription by coupling the light of a white light source to one end of the LPFG, while the output light from the other end was monitored by an optical spectrum analyzer with a scanning range from 600 to 1650 nm and minimum resolution of 2 nm.

3. Spectral characteristics of random-period arc-induced LPFGs

Fig. 2 shows the transmission spectrum of a random-period fiber grating fabricated in DSF. The inset graph shows the random variation of the period around the central period value of 500 μm. The number of periods was 60 with a total length of 30.023 mm, and the range of the random variation was 37.5 μm, with a mean value of 500.39 μm, as shown in the inset table of Fig. 1. The standard deviation of the period of the grating of Fig. 2 was ~10.4 μm, showing that even for a relatively high dispersion in the grating period the LPFG is still formed in the fiber.

In order to evaluate the maximum dispersion in the random period that still allows the formation of the LPFG, several LPFGs with different variation ranges around the central value of 500 μm were fabricated. Fig. 3 shows the transmission spectra of five random period LPFGs (labeled as LPG1, LPG2, LPG3, LPG4, and LPG5) and a LPFG fabricated with a fixed period of 500 μm (upper graph). In all cases, the number of periods was 60, although in some cases deeper peaks were observed for a number of period lower than 60. Table 1 shows the descriptive statistics of the five random period LPFGs of Fig. 3. It is clearly seen that the position of the resonance peaks of the random period LPFGs are very close to the position of the resonance peaks of the fixed

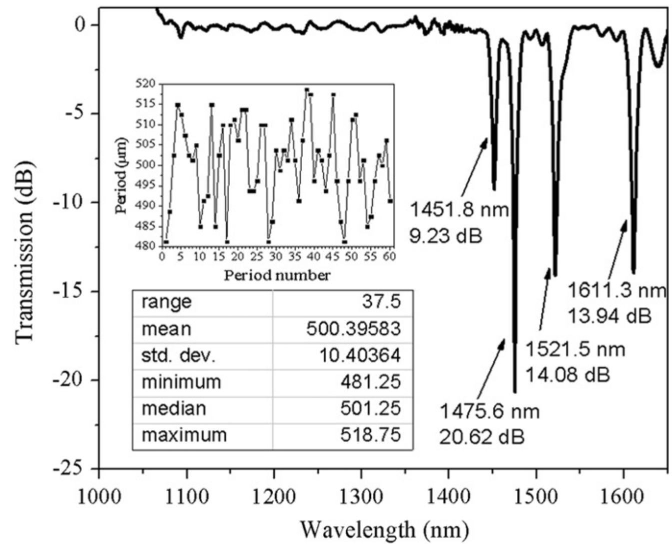

Fig. 2. LPFG with a random period variation in a range of 37.5 μm around 500 μm.

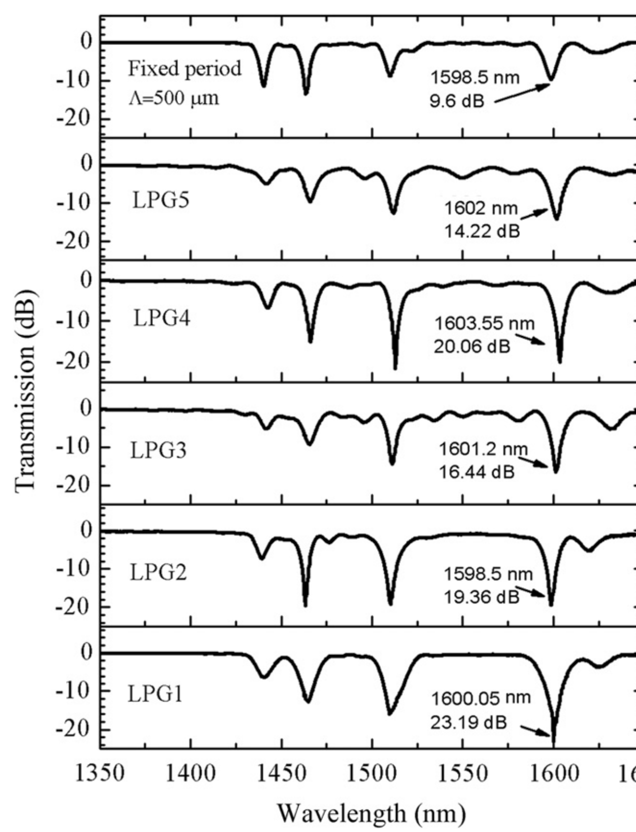

Fig. 3. Transmission spectra of LPFGs with different random period range around the central period of 500 μm.

Table 1
Descriptive statistics of the random period variation for the LPFGs of Fig. 3.

	Range (μm)	Mean (μm)	Std. dev. (μm)	Min. (μm)	Median (μm)	Max. (μm)
LPG1	25	500	8.50	487.5	502.5	512.5
LPG2	50	499.6	15.22	475	493.125	525
LPG3	75	500.875	22.47	462.5	502.5	537.5
LPG4	95	500.6	25.80	450	507.5	545
LPG5	125	501.6	36.98	437.5	497.5	562.5