The Novel Rotation Writing Method of Fiber Bragg Grating in Multicore Fiber

Deng Shunge*, Ma Xin*, Li Xinwan*, and Gao Kan*
*State Key Laboratory of Advanced Optical Communication Systems and Networks, Shanghai Institute for Advanced Communication and Data Science, Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai 200240, China
** No.23 Research Institute of China Electronic Technology Corporation Group, Shanghai, China

Abstract

Through a novel rotation writing method of fiber bragg grating, reflection signal with a low-bandwidth, high-reflection and good-uniformity is acquired and the influence of different factors of novel method are explored.

I. INTRODUCTION

The fiber bragg grating (FBG) is widely used for optical communication and sensing field. There are many techniques of inscribing the FBG into single-mode fibers (SMF), such as transverse holographic method [1]. However, the inscription of fiber bragg grating in multicore fiber (MCF-FBG) is huge challenge because of uniformity. In [2-4], regarding lensing effect and shadowing effect as the primarily rough hurdles, the uniformity becomes better by inserting MCF into a capillary tube when FBG writing. It has been demonstrated that modifying the position of four cores can improve uniformity in [5]. However, these methods are not suitable for commercial production of MCF-FBG.

In this paper, we propose a novel rotation writing method for MCF-FBG fabrication and obtain a low-bandwidth, high-reflection and good-uniformity reflection signal. The FBG is formed due to a periodic change in refractive index in the core. The light intensity received by core has a linear relationship with the change of refractive index. Therefore, each core in MCF can receive a uniform light intensity through rotation. The influence of different factors of novel method are explored, such as single writing time and rotation times.

II. EXPERIMENTAL SETUP

The MCF, produced by YOFC in Wuhan, China, has seven cores, as shown in Fig. 1. The diameter of core is 8μm with 41.5μm core-to-core distance. The fiber cladding has 150μm diameter. The number of each core is order by counterclockwise.

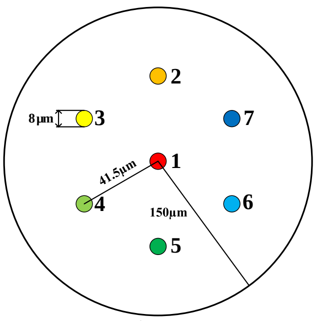

Fig. 1. The side view of MCF with seven cores.

As shown in Fig. 2, this is the schematic of experimental setup of rotation writing. The fiber clamps and rotators are combined to rotate the MCF around the axis. The fiber clamps should have the characteristics of strong clamping force to tighten the MCF and prevent axial displacement of MCF during rotation. The two identical fiber clamps are separately mounted on two uniform rotators. The rotator can be driven by motor or manually. In this experiment, the rotators are manually driven and the accuracy of it is 2°.

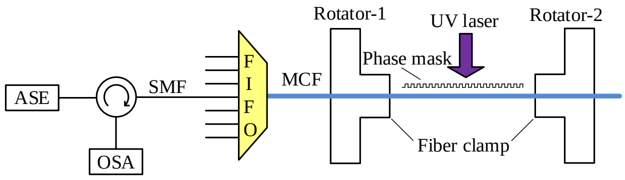

Fig. 2. The schematic of experimental setup of rotation writing.

Before writing, the fiber clamps and rotators should be adjusted in parallel to minimize the MCF jitter during rotation. The two rotators are turned as slowly and synchronously as possible. The distance between two fiber clamps is 180mm. The relationship between distance from rotation-1 and MCF jitter is shown as Fig. 3. The relationship curve is similar to a quadratic function and has a minimum point of MCF jitter. After hydrogenation, remove the coating of MCF and place the area of MCF minimum jitter near the phase mask. The distance between the MCF and phase mask is approximately 100μm.

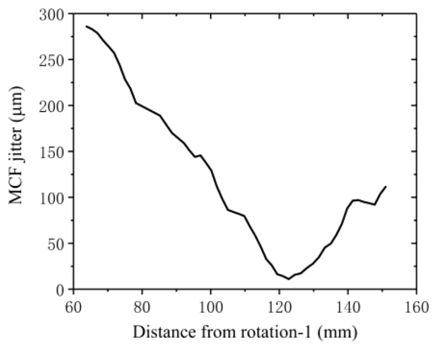

Fig. 3 The relationship between distance from rotation-1 and MCF jitter.

After FBG writing, SMF and MCF is connected through Fan-in and Fan-out (FIFO) to acquire reflection signal. Utilizing the Amplified Spontaneous Emission (ASE) source and the Optical Spectrum Analyzer (OSA), the reflection signal can be obtained through the circulator.

In this experiment, we set up six sets of comparative tests. First of all, traditional fabrication with phase mask was used to writing MCF-FBG without rotation. The writing time is 60s and 90s, representing as sample 1 and sample 2. Then rotation was added into the writing of MCF-FBG. The MCF rotated 6 times and the angle of each rotation was 60°. After each rotation, the writing time is 7s, 10s and 30s, and the next rotation is waited for one minute, representing as sample 3, sample 4 and sample 5. The sample 6 consists of 3 times MCF rotations and 120° each rotation angle with one minute waiting time for next rotation.

III. EXPERIMENTAL RESULTS

Using the MCF-FBG center wavelength of the core 1 as a reference, the shift of center wavelength of each core can be expressed as

$$\Delta\lambda_i = \lambda_i - \lambda_1 (i = 2, 3, ..., 7)$$

where λ_i (1, 2, ..., 7) is the center wavelength of i^{th} core. The uniformity of MCF can be represented as

$$\eta = \sum_{i=2}^{7} (\Delta\lambda_i)^2$$

After data processing of smoothing and filtering, the results of MCF-FBG are shown in Fig. 4. Due to space reasons, sample 1 and sample 4 are selected to exhibit. The central wavelength of each core λ_i has different degree of deviation and reflection power of each of MCF-FBG exist difference. It may be due to the lensing effect and shadowing effect, causing unevenly exposure [2]. The scattered light from other cores may result in multi-peak phenomenon.

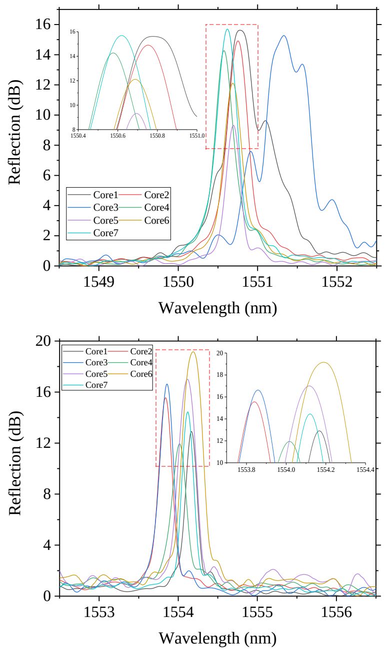

Fig. 4. The results of MCF-FBG. Above: the result of sample 1 with partial enlargement insertion. Below: the result of sample 4 with partial enlargement insertion.

Through rotation writing, MCF-FBG features high reflection, low 3dB bandwidth and good uniformity. As shown in table I, this is a summary table, including the average 3dB bandwidth, maximum and average reflection and the uniformity η. Whether it is a novel rotation writing or traditional fabrication [6], as the single writing time increases, the uniformity η of MCF will deteriorate and most core will have higher reflection and higher bandwidth. This is because the bandwidth and reflection are closely related to the light intensity received by the core. However, there are upper limitation of reflection power. In addition, compared with rotation writing and traditional fabrication, in a reasonable basis of signal writing time, MCF-FBG fabricated by rotation writing has narrower 3dB bandwidth. In the case of same single writing time, when decreasing the number of rotations, the reflection signal will worse uniformity η while the change of bandwidth and reflection power is little.

TABLE I--THE CHARACTERISTIC OF EACH SAMPLES

Sample	Average 3dB bandwidth (nm)	Maximum reflection (dB)	Average reflection (dB)	η
1	0.221	15.694	13.885	0.388
2	0.431	23.087	19.004	1.782
3	0.17	16.907	12.242	0.194
4	0.127	19.159	15.378	0.233
5	0.637	21.07	17.483	0.606
6	0.118	20.843	14.239	0.396

To sum up, through a reasonable choice of single writing time and rotation times, reflection signal with a low-bandwidth, high-reflection and good-uniformity can be obtained by rotation writing method.

REFERENCES

[1] Meltz, G., W_W Morey, and W. H. Glenn. "Formation of Bragg gratings in optical fibers by a transverse holographic method." *Optics letters* 14.15 (1989): 823-825.

[2] Lindley, Emma, et al. "Core-to-core uniformity improvement in multi-core fiber Bragg gratings." *Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation*. Vol. 9151. International Society for Optics and Photonics, 2014.

[3] Min, Seong-sik, et al. "Multicore fibre Bragg grating developments for OH suppression." *Modern Technologies in Space-and Ground-based Telescopes and Instrumentation II*. Vol. 8450. International Society for Optics and Photonics, 2012.

[4] Lindley, Emma, et al. "Demonstration of uniform multicore fiber Bragg gratings." *Optics express* 22.25 (2014): 31575-31581.

[5] Askins, Charles G., et al. "Inscription of fiber Bragg gratings in multicore fiber." *Nonlinear Photonics*. Optical Society of America, 2007.

[6] Yan Fei, et al. "Bandwidth Characteristics of Fiber Bragg Grating Fabricated with Femtosecond Laser Radiation." *Chinese Journal of Lasers* 11 (2013), 147-152

[7] Deng Shunge, Xin Ma, and Xinwan Li. "The Analysis of Angle Resolution of Stress Vector Sensor Based on Optical Fiber Sensing Cable for High Speed Railway Traffic." *Journal of Shanghai Jiaotong University (Science)* 23.1 (2018): 61-65.