Point-by-point inscription of Bragg gratings in a multicore fibre

Andrei Donko, Martynas Beresna, Yongmin Jung, John Hayes, David Richardson, Gilberto Brambilla
Optoelectronics Research Centre, University of Southampton, Southampton, United Kingdom
a.l.donko@soton.ac.uk

Abstract—**Multicore fibre Bragg gratings are fabricated using an ultrafast femtosecond laser via the point-by-point inscription methodology. Independent Bragg gratings are directly written into each core of a multicore fibre with low inter-core crosstalk.**

Keywords: femtosecond laser writing, Bragg grating, multicore fibre, point-by-point.

I. INTRODUCTION

For many years, fibre Bragg gratings have been widely used as a Bragg reflector or band-rejection filter in single core fibres for a wide range of optical sensing, fibre lasers and optical communication applications [1]. More recently, multi-core fibre (MCF) Bragg gratings have attracted new emerging interests in the field of astronomy and space division multiplexed optical transmission [2,3]. For astronomy applications, narrow linewidth spectral filtering of cosmic light is a challenging issue and multicore fibre Bragg gratings can provide an integrated spectral filter function for compact astro-photonic instruments in conjunction with photonic lanterns.

Recently, using a phase mask approach, fibre Bragg gratings have been inscribed in multicore fibres, where the whole cross-section of the fibre was simultaneously illuminated to achieve the same spectral filter in all cores. However, for space division multiplexed application, each core of the MCF is considered as an individual information channel and independent grating inscription of selective cores of the MCF allows for the significant reduction of the number of sources/detectors being used. For this purpose, point-by-point femtosecond laser inscription can provide the necessary refractive index modulation into the specific core by focussing the laser light through a high numerical aperture lens. This technique allows not only writing an individual grating into each core of the MCF, but also providing extra flexibility of grating structure such as chirp or amplitude modulation without significantly modifying the inscription setup. In addition, point-by-point writing does not require the removal of a fibre’s protective coating (polyimide and acrylate are transparent to infrared radiation [4]) and it can be employed in non-photosensitive materials.

Therefore, the point-by-point laser inscription method may be more adequate platform to provide low inter-core crosstalk between neighbouring cores and to fulfil the diversity requirement of the MCF based space division multiplexed applications.

In this paper, point-by-point laser inscription is utilised to inscribe individual gratings with different pitch in a MCF. Three independent Bragg gratings were inscribed in three individual cores of a 7-core MCF with negligible inter-core crosstalk observed.

II. EXPERIMENTAL SETUP

A femtosecond laser system (Pharos, Light Conversion Ltd) operating at 1030 nm with a repetition rate of 1 kHz and a pulse duration of 250 fs was used. The beam was pre-shaped with a 250 µm wide slit orientated parallel to the fibre. The slit was placed before a 0.65 NA objective lens, which was attached to a translation stage (Aerotech) to focus the light into the core. A CCD camera and a dichroic mirror were placed directly above the objective lens, allowing imaging of the fibre and monitoring of the writing process. An exemplary 7-core multicore fibre was then secured to a two-axial translation stage (Aerotech).

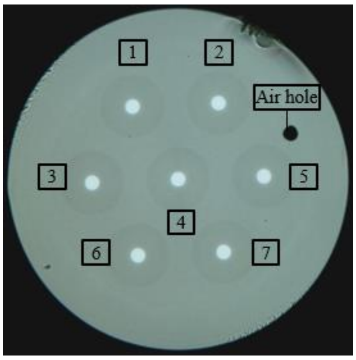

Figure 1. Microscope image of MCF cross section.

Three 3rd order gratings, each 10 mm long, were written in three separate cores. Each grating was written by traversing the fibre at a constant speed of 0.1 mm/s. The pitch of the grating was controlled by synchronising the translation stage position with a pulse picker within the laser system. The refractive index modification in the glass was achieved by a single pulse (2.1 µJ) irradiation. Gratings were characterized in-situ during writing with a 1550 nm EDFA source with 20 nm bandwidth and an optical spectrum analyser (Yokogawa). Each core was addressed by using fan-in and fan-out device connecting each core with 7-core MCF to a standard single-mode telecommunication fibre.

The 7-core MCF used in our experiment was fabricated in-house using the stack-and-draw technique. It has seven single mode cores of diameter of d~10 μm and numerical aperture of NA~0.12 in a hexagonal array, as shown in Fig. 1. The average core pitch is ~50 μm and the cladding diameter is 198 μm.

III. Results and Discussion

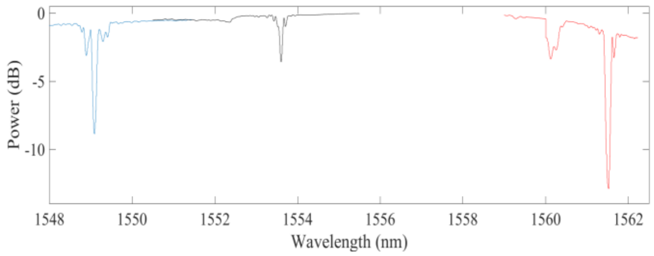

Figure 2. Transmission spectrum of the three gratings from three independent separate cores.

Three gratings were written at Bragg wavelengths of λ_B~1549, 1554 and 1562 nm, with extinction ratios of 7.5, 3.5 and 11.5 dB, into cores 6, 5 and 3 respectively (fig. 2). Cladding modes were adequately suppressed for the 1549 and 1554 nm gratings. However, cladding mode coupling occurred and accumulated for the 1562 nm grating, leading to radiation mode coupling losses of approximately 3 dB at λ~1560nm [5,6]. The inscription process caused an insertion loss of 0.3 dB at λ=1554 and 1562 nm and 0.8 dB at λ=1549 nm. Bandwidths of 0.1 nm were achieved for the 1549 and 1562 nm grating and 0.05 nm for the 1554 nm grating. A CCD image of the 1549 nm grating can be seen in figure 3.

A variation of 3.5 dB, occurred between the 1549 and 1554 nm gratings. Variation in the extintion ratio across all three gratings can be attributed to inaccuracy of laser focus positioning within the core of the fiber. However, the consistency of the results can be improved after further refinement to the experimental setup.

Figure 3. CCD camera image of 1549 nm grating

IV. Conclusion

Using a direct laser inscription technique, independent Bragg gratings were successfully fabricated in selected cores of a multicore fibre. This approach allows addressing each core separately without increasing the inter-core crosstalk and potentially useful for recent space division multiplexed transmission and shape sensing applications.

V. Acknowledgments

This work was conducted by the Optoelectronics Research Centre at the University of Southampton. We would like to thank the Royal Academy of Engineering, UK for funding this research.

References

[1] A. Kersey et al., "Fiber grating sensors", J. Lightw. Technol., vol. 15, no. 8, pp. 1442-1463, Aug. 1997.

[2] E. Lindley, S. Min, S. Leon-Saval, N. Cvetojevic, J Lawrence, S. Ellis, J. Bland-Hawthorn, “Writing Bragg gratings in multicore fibers,” Optics Express vol. 22 no. 25 2014.

[3] C. Wang, Z. Yana, Q. Suna, Z. Suna, C. Moua, J. Zhanga, A. Badmosa, L. Zhanga, “Fibre Bragg gratings fabrication in four core fibres,” Proceeding of SPIE, vol. 9886, no. UNSP 98860H, 2016.

[4] S. J. Mihailov, D. Grobnic, C. W. Smelser, "Efficient grating writing through fibre coating with femtosecond IR radiation and phase mask," Electron. Lett., vol. 43, no. 8, pp 442, 2007.

[5] V. Mizrahi, J.E. Spie, “Optical properties of photosensitive fibre phase gratings,” Journal of Lightwave Technolgy, vol. 11, no. 10, 1993

[6] T. Erdogan, “Cladding-mode resonances in short – and long-period fiber grating filters,” J. Opt. Soc. Am. Vol. 14, no. 8, 1997.