Optical Fiber Technology 34 (2017) 30–35

Contents lists available at ScienceDirect

Optical Fiber Technology

www.elsevier.com/locate/yofte

Regular Articles

Metal-coated Bragg grating reflecting fibre

Yu.K. Chamorovskiy *, O.V. Butov, A.O. Kolosovskiy, S.M. Popov, V.V. Voloshin, I.L. Vorob'ev, M.Yu. Vyatkin

Kotel'nikov Institute of Radio-Engineering and Electronics of RAS, Mokhovaya 11, bld. 7, Moscow 125009, Russia

A R T I C L E I N F O

Article history:
Received 14 September 2016
Accepted 31 December 2016
Available online 6 January 2017

Keywords:
Optical fibres
Fibre optics sensors
Fibre Bragg gratings
Metal coating

A B S T R A C T

High-temperature optical fibres (OF) with fibre Bragg gratings (FBG) arrays written over a long length and in-line metal coating have been made for the first time. The optical parameters of the FBG arrays were tested by the optical frequency domain reflectometer (OFDR) method in a wide temperature range, demonstrating no degradation in reflection at heating up to 600 °C for a fibre with Al coating. The mechanical strength of the developed fibre was practically the same as "ordinary" OF with similar coating, showing the absence of the influence of FBG writing process on fibre strength. Further experiments are necessary to evaluate the possibility of further increases in the operational temperature range.

1. Introduction

Optical fibres (OFs) with inscribing arrays of fibre Bragg gratings (AFBG) are interesting for different types of fibre devices such as fibre sensors [1,2] and fibre lasers [3]. The most advanced method of manufacturing such AFBG is to write them directly in-line during the fibre drawing process. This gives the possibility of making a huge number of fibre Bragg gratings (FBG) in a single OF. The parameters of these FBG could be constant or variable along the OF length. Such a method also preserves the high mechanical strength of OF and results in their geometrical homogeneity [4–6]. One of the main restrictions for using OF is thermal resistance, determined mainly by the OF coating properties and BG degradation during heating. Until the present, all OF with in-line writing AFBG have different types of polymer coatings, and an upper temperature range less than 300 °C [7]. Higher operating temperatures are available by applying metal coating during the OF drawing process [8], but AFBG in such OF were inscribed only by the point-by-point method, which includes the process of coating removal, single BG writing, and recoating, moving to the next OF point and reiteration of all steps [9].

The development of OF with in-line written AFBG as well as in-line application of metal coating for the same OF is presented here for the first time. This gives the possibility to obtain a wide temperature range for a large AFBG, and to preserve a high mechanical strength. The experimental results of such OF tests under heating up to 600 °C are presented for both optical-FBG reflectivity and the mechanical properties, including lifetime estimation.

2. Material and methods

The scheme of experimental setup has shown on Fig. 1. In-line writing of AFBG during the drawing process was performed directly through a phase mask without the use of an interferometric scheme [10]. Immediately under this position, the metal coating applicator was installed, and a metal coating was placed on an OF using the well-known frozen method. We used Al coating, but other metal coating such as Cu, Au, having higher melting temperature could be applied after some modification of technology. OF has a SiO_2–GeO_2 core, with an index difference of about 0.02 and a cut-off wavelength at 1400 nm. The OF's outer diameter is 125 μm and the coating diameter is about 160 μm. A standard KrF excimer laser with 248 nm radiation wavelength was used as the UV source. The pulse energy was about 35–40 mJ, and its duration was 7–8 ns. The beam was focused with the help of a cylindrical lens up to an energy density of 400 mJ/cm^2. The phase mask working length is ~10 mm, its period 1070 nm, and the distance between mask and OF boundary was as little as 0.2 mm.

OF with AFBG was made having the length of each individual FBG of about 10 mm, and the distance between adjacent FBGs also about 10 mm. Typical OF sample length was 100 m.

Measurements of reflecting signals were performed using the OFDR method [11] with the Luna 4600 device. The OF under heating test had a typical length of 3 m, which was placed into an electrical furnace. The test procedure was as follows:, the furnace was programmed to heat from room temperature with a step of 100 °C

* Corresponding author.
E-mail address: yurichamor@gmail.com (Y.K. Chamorovskiy).

http://dx.doi.org/10.1016/j.yofte.2016.12.008
1068-5200/

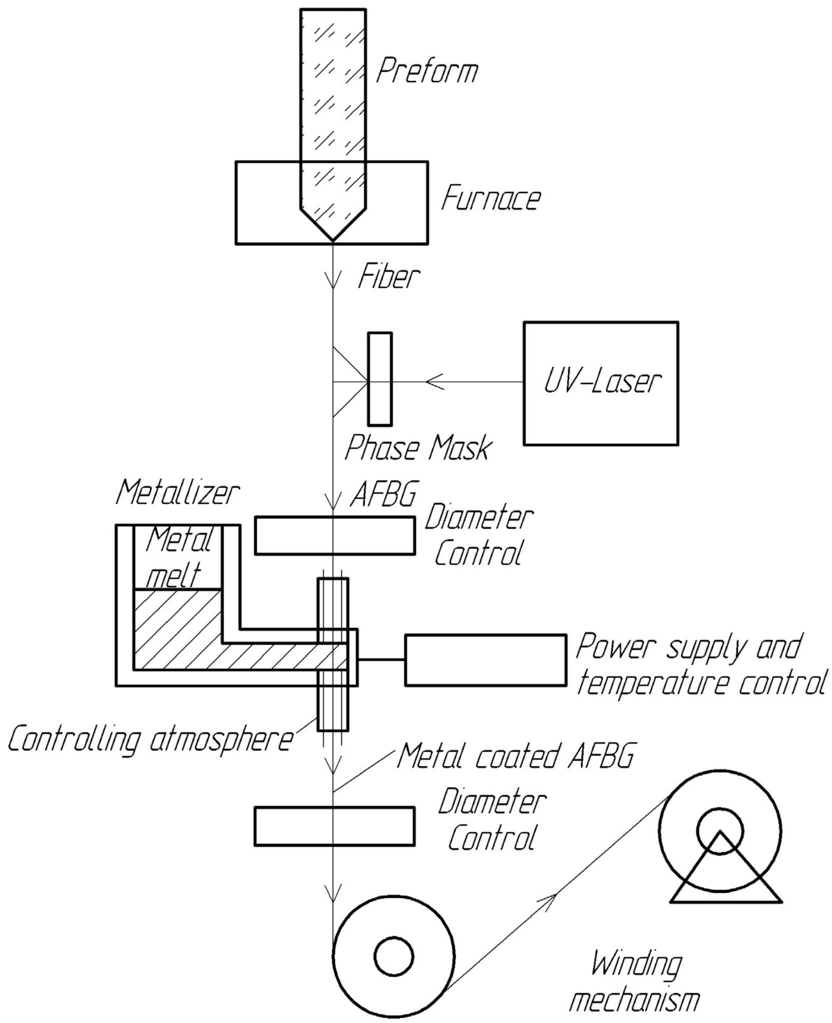

Fig. 1. The scheme of experimental setup.

for about 15 min. Than, at each test temperature OF was held for about 30 min. At these points, the maximum reflecting wavelength was measured as well as the shape of the reflecting signal. The maximum heating temperature was 600 °C; for several tests it was 500 °C. After heating to the maximum temperature, heating was switched off, and the furnace with the OF was cooled naturally. The reflecting signals were measured at 500 °C, 400 °C etc., without fixing at these points.

The parameters of AFBG were determined by the following procedure: at a given temperature the maximum reflecting wavelength was determined in low-resolution operating mode of Luna 4600 (OFDR), than at this wavelength the reflecting signal was measured in high-resolution mode and was saved to the PC. Two measurements need because in low-resolution mode OFDR has more dynamic range than in high-resolution mode and more easily to find AFBG wavelength maximum of reflection.

3. Results and discussion

The typical reflecting signal pattern for such an OF is presented in Fig. 2. Its initial part corresponds to the case of laser-off, while the right part corresponds to the laser-on state. The laser works with duty cycle 50% and one can see it by meander-like signal. The structure of reflective signal repeats each 20 mm (where 10 mm – FBG and 10 mm – Rayleigh scattering signal only). It is clearly seen that a signal amplitude increase of about 30 dB resulted from UV irradiation. Some parasitic modulation of FBG reflecting signal is clear seen at Fig. 2 and results from imperfection of laser beam.

The reflecting signal from the lengths without UV irradiation was due to Raleigh scattering only, and from lengths under UV irradiation due to both Raleigh scattering and FBG. The difference between these two signal levels will be hereafter denoted as the contrast parameter of the reflecting signal.

Reflecting spectra for Al-coated OF with written ABG are presented in Fig. 3. First spectrum corresponds to 2 m metal coated AFBG (100 FBGs) and is measured by OFDR technique. Second spectrum corresponds to 20 m of the same metal coated AFBG (1000 FBG) and is measured by OSA Yokagawa AQ6370, using combination of power source and optical circulator. It is clearly seen that no significant difference in the reflection spectra of 1000 FBGS and 100 AFBG. It calls of good repeatability of the AFBG writing process. The reflective bandwidth can be evaluated as 0.25–0.3 nm (at the level of −3 dB). Total losses of developed fibres at the wavelength 1550 nm are strongly dependent on the number of FBGs, UV-laser power, the core composition and index refraction profile, as well as the properties of the metal coating [8,10]. The observed magnitude of optical losses for developed fibres are approximately in the range of 0.001–0.01 dB at each FBG.

Besides OF with an Al coating, similar experiments were performed for OF with standard acrylate coating, drawing from the