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EVALUATION OF THE EFFECTIVENESS OF THE EFFECT OF PHOTOSENSITIZATION ON THE SPECTRAL CHARACTERISTICS OF THE FIBER BRAGG GRATING

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Currently, fiber Bragg gratings obtained on the basis of photoinduced optical fibers doped with a high concentration of germanium oxide are used as highly sensitive sensors.

However, it is worth noting a significant drawback – the manufacturing technology of optical fibers doped with germanium is expensive.

When recording Bragg gratings in a standard telecommunication fiber, where the molar concentration of germanium in the fiber core is from 3 % to 5 %, interference occurs due to very low and insufficient light sensitivity. Thus, an important role is played by solving the problem of low photosensitivity of standard telecommunication fibers for recording Bragg gratings.

This paper presents the results of studies of the spectral characteristics of fiber Bragg gratings based on standard telecommunication fibers pre-saturated with hydrogen to increase photosensitivity. According to the results obtained, it was found that under the action of UV radiation in the presence of hydrogen, the photosensitivity of the fiber increases and the Bragg wavelength shift is associated with the saturation of the fiber with hydrogen, the effective modulation amplitude of the induced refractive index is equal to 1.2 with a refractive index of 1.438. This work proves that the VBR recorded in the S pre-saturated in hydrogen for 12 days is characterized by increased photosensitivity.

The experimental results obtained make it possible to use a Bragg fiber array based on a standard telecommunications optical fiber saturated with hydrogen in the field of telecommunications, seismology, engineering geology as fiber-optic sensors of pressure, deformation, temperature, rotation and rotation, including in extreme environmental conditions

Keywords: electronics, telecommunications, Bragg grating, optical fiber, simulation

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1. Introduction

Most communication networks currently use fiber optics as a medium for transmitting information. In the second half of the last century, there was a real evolutional ideas about the future of telecommunication systems. This revolution made possible by the beginning of a new stage in the development of fiber optics. Solutions were found that allowed the use of optical fiber to transmit information.

At first glance, it may seem that the main application of fiber light guides is their use in communication systems.

In addition to applications in telecommunications, optical fibers are also used in the fast-growing field of fiber-optic sensors. Despite improvements in optical fiber production technologies and advances in the field as a whole, connecting basic optical devices such as mirrors, long-wave filters and partial reflectors with optical fiber remained a promising but unsolved task.

However, with the advent of the ability to change the refractive index in a single-mode optical fiber by absorbing ultraviolet radiation, the matter has acquired a different character.

Kazakhstan ranks ninth in the world in terms of area, but the population density here is one of the lowest [1]. A small population is dispersed over a large area. Because of this, there was an opinion that the quality of the call center is affected by the territorial location and the specificity of the language dialect. Due to these, at the moment, fiber-optic sensors are widely used on the territory of the Republic to measure deformation and other aspects, as well as to improve the quality of communication on the territory of our country.

With the development of the fuel and energy complex, the extraction of hydrocarbon raw materials, the joint deformation of the underground pipeline and the soil massif in complicated conditions is a little-studied problem, which often leads to emergency destruction of the pipeline.

In modern engineering geology, the analysis of terabytes and even petabytes of seismic, geophysical, and field data becomes an everyday task.

The above determines the need to monitor the stress state of the pipe walls, in order to promptly apply preventive measures.

The most complete and promising technical solution for extreme operating conditions is the use of optical measurement principles on which fiber-optic sensors (VOD) are based. The use of sensitive optical fiber as WATER and measuring communication lines is an effective solution both in terms of mechanical properties and radiation resistance properties of optical fibers.

Therefore, the use of the Bragg lattice as a sensitive element of fiber-optic sensors is relevant.

2. Analysis of literature data and problem statement

Currently, fiber Bragg gratings are widely used in optical fibers and flat waveguides for sealing channels along the wavelength (WDM technology), in filtering the optical signal [2], in sensors for recording changes in environmental conditions, such as temperature, pressure, deformation, presence or absence of chemicals [3]. Fiber-optic sensors based on fiber Bragg gratings have a number of inherent advantages over electrical resistance meters, such as low weight, small dimensions, immunity to electromagnetic interference, lack of a power source [4]. Fiber Bragg grating with phase shift as an important basic optical element has found wide application in the production of optical devices due to the narrow line width and good filtering characteristics. Fiber lasers and fiber sensors based on them have important prospects for use in the defense sector [5].

Standard VBR sensors are usually applied to a single-mode optical fiber (SMF), which consists of a cylindrical inner core surrounded by a shell. The refractive index of the core is higher than that of the shell. SMF allows to transmit a single beam of light over a long distance, which makes it suitable for various applications [6]. FBG technology is widely used in engineering and scientific research. It is a mature technology in the field of optical fiber detection. It can be made in various geometric shapes according to the requirements and is widely used to measure deformation and temperature in various fields [7].

The paper [8] presents the results of studies of the VBR structure sensitive to changes in the refractive index of the medium surrounding the optical fiber, one of the currently used methods for measuring changes in the electromagnetic field using VBR is, for example, coating the surface of an optical fiber at the place of manufacture of VBR with a thin layer of liquid crystal [9] or so the so-called magnetic fluid [10]. Changes in the position of liquid crystal or magnetic liquid molecules caused by changes in the electromagnetic field cause a change in their refractive index, which, in fact, is noticeable by the change in the transmission coefficient of modes of higher orders.

In [11], an optical scheme for registering a Bragg fiber lattice using an argon-ion laser emitting a beam with a wavelength of 488 nm is described. Due to the excitation of the longitudinal mode, the core with high sensitivity was exposed to light. However, to avoid instability during recording, the argon-ion laser must be isolated from reflected light. This is not the most convenient method when recording fiber.

There are many ways to increase the photosensitivity of standard optical fibers: increasing the concentration of germanium dioxide in the core of the fiber [12], alloying with chemical elements such as boron, tin, nitrogen, phosphorus, antimony. However, despite the fact that a number of compositions with increased photosensitivity have been proposed, optical fibers based on them are difficult to manufacture and, in addition, have material and waveguide characteristics different from standard ones, which leads to inconveniences of the experimental process.

Due to the constant intensity of interference inside the optical fiber, the effective mode index increases when exposed to ultraviolet radiation.

[12] showed that the sign of a change in the refractive index caused by light in an optical fiber doped with Ge-helium was positive when it was irradiated from the outside. At the same time, it will be possible to use hydrogen loading, which will increase the refractive index caused by light in an optical fiber doped with Ge-helium.

An experiment was carried out to record the VBR in a single-mode optical fiber with the addition of germanium dioxide GeO_2 into the core as an alloying impurity without loading into hydrogen.

In connection with these disadvantages, all this suggests that it is advisable to conduct research arising in the doping process, of considerable interest is to increase the photosensitivity of optical fibers without significantly changing their own characteristics. It is proposed to saturate the fiber with hydrogen, which is capable of increasing the induced refractive index of standard telecommunication fibers by an order of magnitude.

3. The aim and objectives of the study

The aim of the study is to create, on the basis of experimental research, a new version of the fiber Bragg lattice with an effective parameter of spectral characteristics by photosensitization of a standard telecommunication optical fiber. This will make it possible to use a Bragg fiber array based on a standard telecommunications optical fiber saturated with hydrogen as fiber-optic sensors.

The purpose of this work is to create a new version of a fiber Bragg lattice with an effective parameter of spectral characteristics by photosensitizing a standard telecommunication optical fiber, which will allow using a fiber Bragg matrix based on a standard telecommunication optical fiber saturated with hydrogen as fiber-optic sensors.

To achieve the goal , the following objectives were set:

– increase the photosensitivity of optical fibers based on an experiment to record a fiber-optic Bragg lattice with an effective spectral characteristic;

– experimentally compare the spectral characteristics of fiber Bragg gratings based on optical fibers highly sensitive doped with germanium oxide and pre-saturated in hydrogen according to the results of the experiment.

4. Materials and methods of research

To record fiber Bragg gratings into a standard telecommunication optical fiber, in order to study and analyze the spectral characteristics of the FBG, a measuring system was developed in which both the phenomenon of light coupling with the shell and the Bragg main resonance are used. This measuring system makes it possible to study fiber-optic structures with modulated refractive index, determine the main parameters and properties of these structures and the differences in the spectral characteristics of typical structures without tilt and with tilt (FBG and TFBG) [13].

The experiment used photosensitive optical fibers, the core of which is doped with germanium (35 mol %), and standard telecommunication single-mode optical fibers.

The phase mask method was used to record Bragg lattices. The phase mask technique used for recording fiber-optic arrays has advantages over the traditional holographic method due to a simpler recording setup and greater reproducibility of the characteristic. In particular, the use of a phase mask relaxes the strict requirements for the coherence of ultraviolet radiation. On the other hand, in order to photoinduce a change in the index in the core of the fiber, light absorption must occur.

Atkins measured the absorption spectrum in a standard single-mode germanium-doped fiber with a wavelength of only 200 nm [14]. The results show that a light source in the spectral region of UV radiation from 228 to 253 nm is most effective at photoinducing changes in the refractive index in such an optical fiber region. Therefore, let's use an excimer laser with a wavelength of 193 nm as a light source and applied the phase mask technique to record a fiber-optic lattice.

The radiation source is an excimer laser ArF (193 nm) (Germany).

5. Results of the study of the Bragg fiber lattice in optical fiber

5. 1. Recording of a fiber-optic Bragg lattice with an effective spectral characteristic into an optical fiber saturated with hydrogen

To implement fiber Bragg gratings into a standard telecommunication optical fiber, in order to study and analyze the spectral characteristics of FBGs, a measuring system was developed in which both the phenomenon of light conjugation with the cladding and the main Bragg resonance were used. This measuring system makes possible to study fiber-optic structures with modulation of the refractive index, determine the main parameters and properties of these structures and the differences in the spectral characteristics of typical structures without tilt and with a tilt (FBG and TFBG) [15].

The advantage of the experiment was the development and use of a special chamber for saturation an optical fiber with hydrogen.

The block diagram of the experimental setup to record optical fiber Bragg gratings is shown in Fig. 1.

According to the structural diagram, UV radiation is directed through a system for positioning and forming UV radiation, consisting of a lens (O), a polarizer (P) and a half-wave plate (λ/2) to a section of a single-mode optical fiber connected to a radiation source and a spectrometer.

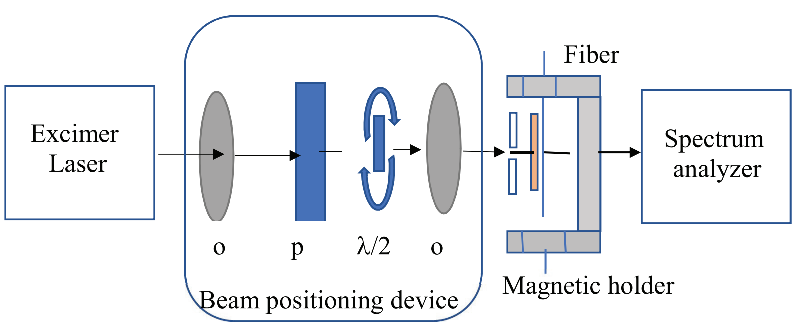

Fig. 1. Block diagram of the Bragg grating recording by the phase mask method

The experiment used photosensitive optical fibers, the core of which is doped with germanium (35 mol %), and standard telecommunication single-mode optical fibers.

The FBG recording with the placement of the optical fiber on the phase mask is performed in a single-pulse order, at an exposure time of 15 s, 30 s and 60 s. As a beam splitter, let's use a phase mask from Ibsen Photonics (Denmark), optimized for operation in the +1/–1 mode of diffraction of the recorded radiation. The phase mask is holographic and provides a period accuracy of +/0.01 nm. The phase mask parameters are shown in Table 1.

Table 1

Phase mask parameters

Parameter	Values
Period, nm	400÷1800
Radiation wavelength, nm	193÷435
Material	UV quartz glass
Uniformity period, nm	±0.01

The mask, according to the requirements, is installed with a constant period of 1080 nm. The phase mask defines the interference image corresponding to the modulation period of the refractive index [16]. In contrast to the scheme based on the Talbot interferometer [17], the period of the interference pattern is fixed. With the help of the holder, the center wavelength of the reflection emitted by the FBG radiation can be changed in a certain spectral range, controlling the pre-stress. In the process of recording, the readings of the spectrum analyzer make possible to determine whether the characteristics of the recorded Bragg grating correspond to the required values.

An ArF excimer laser (193 nm) was used as a radiation source. The parameters are shown in Table 2.

Table 2

ArF excimer laser parameters

Specifications:	
Laser type	ArF
Wavelength, nm	193
Energy, mJ	100
Average power, W	200
Frequency, Hz	5000
Pulse duration, ns	14
Sustainability (σ) %	>2

The advantage of this experiment was the saturation of the optical fiber with hydrogen and the use of a special camera for this.

The grating was created according to the results of experiments on the basis of the process of hydrogenation of the optical fiber with a length of 10 meters for one, three, five and twelve days at a temperature of 25 °C in a chamber under a pressure of 180 bar. The grating was written into a standard SMF-28 single-mode optical fiber using a 100 mJ excimer laser operating at a wavelength of 193 nm with a repetition rate of 14 Hz. The phase mask method was also used [18]. With a period of 1080 nm. As a result, a 10 mm long FBG was obtained. To stabilize the operation of the grid recording system, a constant temperature was maintained in the room.

The depth of refractive index modulation depends on the exposure time of the optical fiber in hydrogen.

In most cases, periodic changes in refractive index are produced only in the fiber core. This is due to the fact that it is the fibrous core that undergoes photosensitization and during the execution of the structure, for example, when using ultraviolet light, the refractive index in the core changes mainly. Therefore, at the point where the FBG structure is formed, at the interface between the active zone and the cladding, the effective refractive index changes, which leads to poor refraction of light towards the cladding. The solution to the problem of reducing or even eliminating this phenomenon is to subject the entire optical fiber to photosensitization, i.e. both the core and the cladding.

The phase mask technique, used to record the fiber optic gratings has advantages over the traditional holographic method due to easier recording setup and better performance repeatability. In particular, the use of a phase mask relaxes the strongest requirements for coherence of ultraviolet radiation. On the other hand, in order to photoinduce the index change in the fiber core, light absorption must occur. Atkins measured the absorption spectrum in a standard germanium-doped single-mode fiber with a wavelength of only 200 nm [19].

The results show that a light source in the UV spectral region from 228 to 253 nm is the most effective in photoinducing refractive index changes in this optical region of the fiber. Therefore, the excimer laser with a wavelength of 193 nm as a light source was utilized and a phase mask technique was applied to write the fiber optic grating.

Fig. 2 shows the transmission and reflection spectra of a fiber Bragg grating obtained when the fiber is irradiated through a zero-order phase mask (period 1080 nm) at an intensity of 100 mJ/cm^2/pulse. An ArF excimer laser (193 nm) with a repetition rate of 14 Hz was used to irradiate a 10 mm Bragg grating for 11 minutes.

The Bragg wavelength of this fiber grating was centered at 1560.2 nm, and its bandwidth, measured at full width at half maximum (FWHM), was 0.53 nm. Since the period of the phase mask is known, the effective mode index is estimated at 1.447 depending on the Bragg conditions.

$$\lambda_B = 2_{n_{eff}} \Lambda, \quad (1)$$

where λ_B is the Bragg wavelength, n_{eff} is the mode effective action index, and Λ is the fiber grating period. For a homogeneous grating, the maximum reflection coefficient can be expressed as [20].

$$R_{\max} = \tanh^2(kL), \quad (2)$$

$$k = \frac{\pi \Delta n \eta}{\lambda_B}, \quad (3)$$

where k is the coupling coefficient, Δn is the change in the refractive index, L is the grating length and η is the fraction of light propagating in the core. The cut-off wavelength of our fiber was 1199 nm, so the normalized frequency V was 1.848 at 1560 nm. When using coefficients (2) and calculating η=0:62 for a dispersive-shifted fiber at a normalized frequency, the change in the refractive index in the optical fiber was estimated as 2.5×10^{-4}.

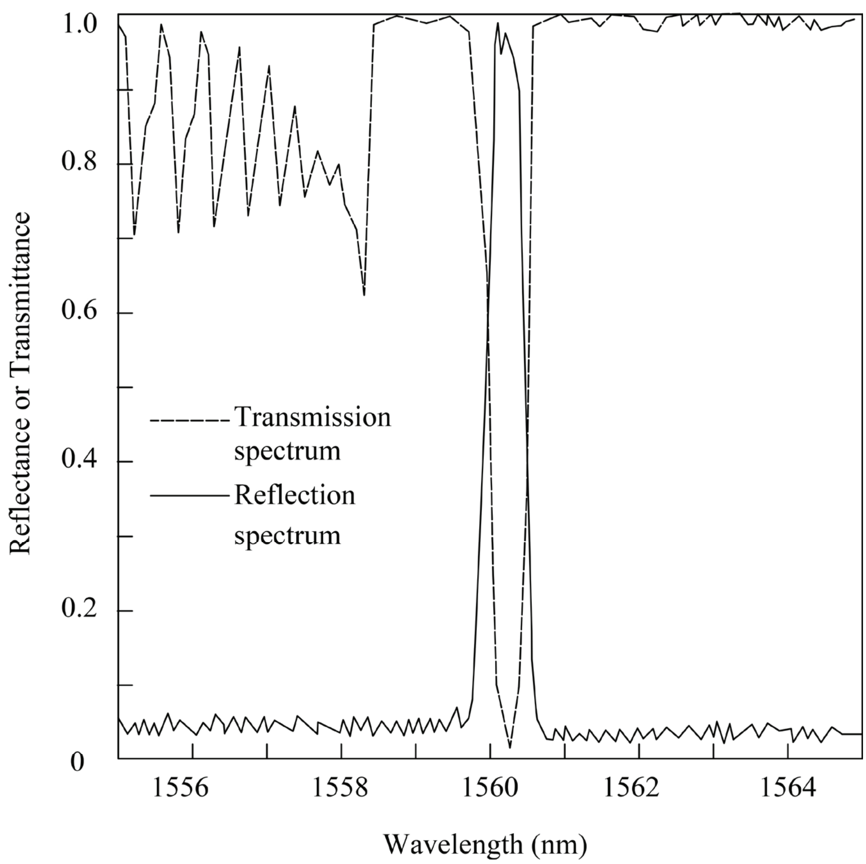

Fig. 2. Emission and reflection spectra of a typical Bragg fiber grating (λ_B=1560.2 nm) [19]

In the transmission spectrum in Fig. 2, the mentioned feature appears in the short-wavelength side of the Bragg peak.

However, as in the reflection spectrum, only the main Bragg peak appears without corresponding signs. Since there is no significant change in UV loss in this spectral range, it is assumed that this loss is not due to the illumination of the fiber core as a result of grating writing.

By the absorption of UV light in the area of the core, in contrast to the transparency of the cladding to ultraviolet light, the refractive index must change from the interface between the cladding and the core, and gradually expand in depth using the recording technique.

By a measuring device (Fig. 1) application, a fiber Bragg grating (FBG) was recorded into an optical fiber (OF).

5. 2. Analysis of spectral characteristics of fiber Bragg gratings

Beforehand, several standard telecommunication optic fibers 10 m long were placed in a hydrogen chamber and kept for 12 days. Then, after 1 day, an OB sample was taken out and a 10 mm Bragg grating was recorded for 15 seconds. Recording was also made for 30 s. and 60 s on a segment of the same sample. Based on the results of experimental measurements using a Yokogawa AQ6370D spectrum analyzer, the transmission spectra of the induced structure were obtained, which are shown in Fig. 3.

With the use of a measuring device (Fig. 1), let's record a fiber Bragg lattice (FBG) into an optical fiber (S).

Previously, several standard telecommunication optical fibers with a length of 10 m were placed in a hydrogen chamber and kept for 12 days. Then, after 1 day, the samples were taken out and the Bragg lattice was recorded with a length of 10 mm for 15 seconds. On a segment of the same sample, recording was also performed for 30 s and 60 s. According to the results of experimental measurements using the Yokogawa AQ6370D spectroanalyzer, the transmission spectra of the induced structure are obtained, which are shown in Fig. 3.

Fig. 4 shows the transmission spectrum of the fiber Bragg lattice FB recorded by ultraviolet ultraviolet radiation for 15, 30 and 60 seconds in an optical fiber soaked in hydrogen for 3 days.

Fig. 5 shows the transmission spectrum of the fiber Bragg lattice FB recorded by ultraviolet ultraviolet radiation for 15, 30 and 60 seconds in an optical fiber soaked in hydrogen for 5 days.

Fig. 6 shows the transmission spectrum of the fiber Bragg lattice FB recorded by ultraviolet ultraviolet radiation for 15, 30 and 60 seconds in an optical fiber soaked in hydrogen for 12 days.

In Fig. 3, no change in the modulation of the FBG transmission was found. Therefore, when the OM is kept in hydrogen for 1 day, the saturation level is low. The optical transmission coefficient is very small.

Fig. 4–6 show the noticeable shift in the FBG wavelength as the grating recording time increases. The depth of refractive index modulation depends on the exposure time of the optical fiber in hydrogen.

In consequence of the constant intensity of interference inside the optical fiber, the effective mode index increases when exposed to UV radiation.

In [19] it is shown that the sign of a change in the refractive index caused by light in an optical fiber doped with Ge-helium was positive when it was irradiated from the side.

The experiment was carried out to write FBGs into a single-mode optical fiber, with the addition of germanium dioxide GeO_2 to the core as a dopant without loading in hydrogen.

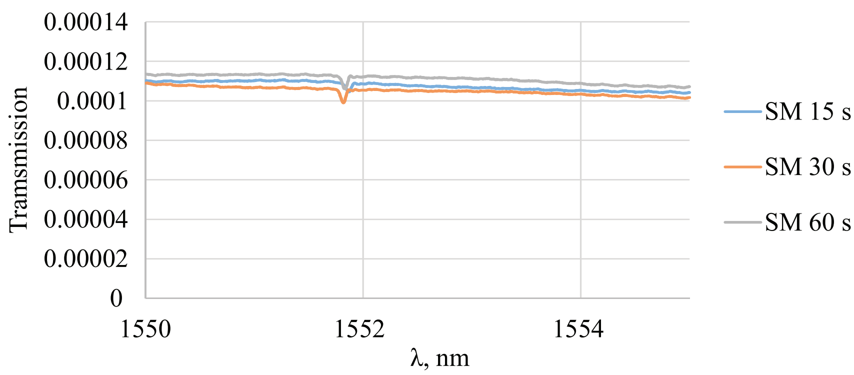

Fig. 3. Transmission spectrum of Fiber Bragg Grating recorded by Ultraviolet radiation for 15 s, 30 s, and 60 seconds in an Optical Fiber , held in hydrogen for 1 day

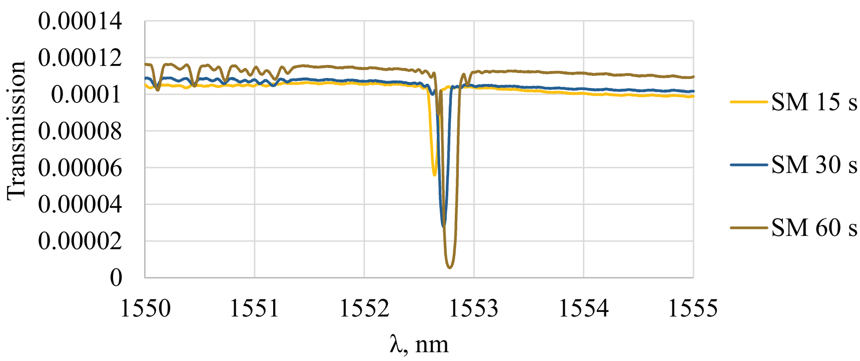

Fig. 4. Transmission spectrum of Fiber Bragg Grating recorded by Ultraviolet radiation for 15 s, 30 s, and 60 seconds in an Optical Fiber kept in hydrogen for 3 days

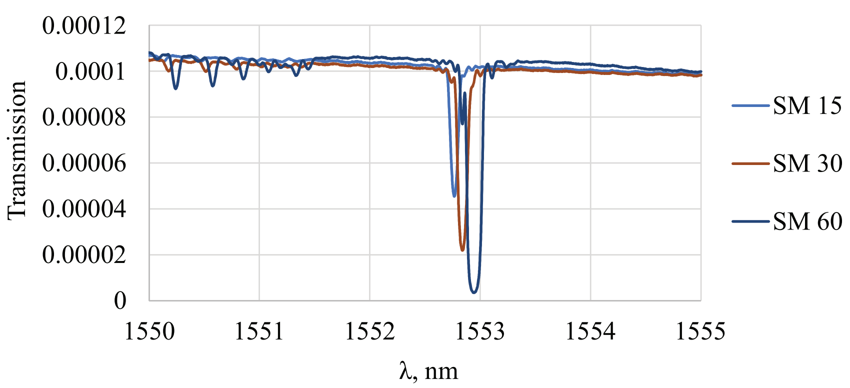

Fig. 5. Transmission spectrum of Fiber Bragg Grating recorded by Ultraviolet radiation for 15 s, 30 s, and 60 seconds in kept in Optical Fiber hydrogen for 5 days

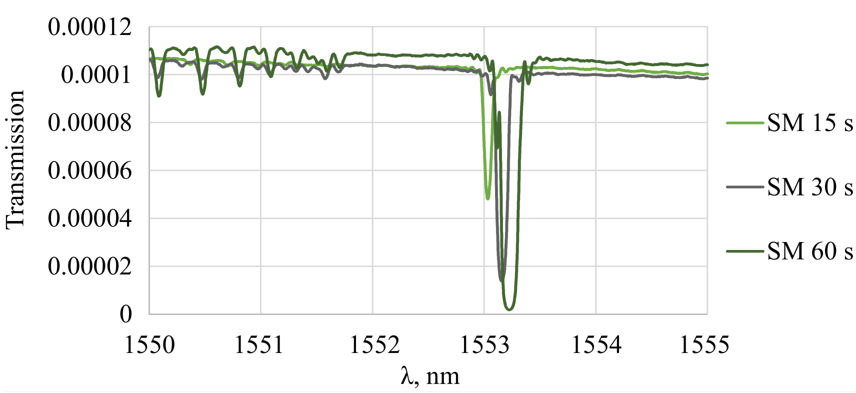

Fig. 6. Spectrum of Fiber Bragg Grating transmission recorded by Ultraviolet radiation for 15 s, 30 s, and 60 seconds in in Optical Fiber kept in hydrogen for 12 days

It is clear that to increase the photosensitivity of a fiber, the GeO_2 concentration in its core has to be increased to 12, 16, and 18 mol %. The method of doping preforms for pulling optical fiber out with germanium dioxide (GeO_2) is the simplest, most efficient, and gives a time-invariant photosensitivity gain.

The disadvantage of the chosen method includes an increase in the linear optical loss of the fiber. For example, for the birefringent OM used in this work with a straining elliptical shell with a GeO_2 content of 16 mol. % loss is about 18 dB/km at 1550 nm.

During the experiment, the transmission spectra were obtained when recording FBGs in an OF with a GeO_2 concentration in its core. Fig. 7–9 show the spectra of FBG transfer to OF with impurities of germanium and FBG saturated with hydrogen.

The measurements were carried out in the range from 1545.6 to 1555 nm. wavelengths with a step of 0.02. Table 3 shows the data at the main points of the wavelength range.

Table 4 shows the data obtained when exposed to ultraviolet radiation on an opto fiber for 30 seconds.

Table 5 shows the data obtained when exposed to ultraviolet radiation on an opto fiber for 30 seconds.

The measurement results were used to determine the Bragg resonance wavelength and Δn is the amplitude modulation of the induced refractive index of the Bragg grating for single-mode fiber doped with germanium oxide (GeO_2) and for single-mode fiber pre-loaded in hydrogen (Table 6).

Fig. 11 shows the modulation of the RI refractive index during the duration of exposure to UV Ultraviolet radiation.

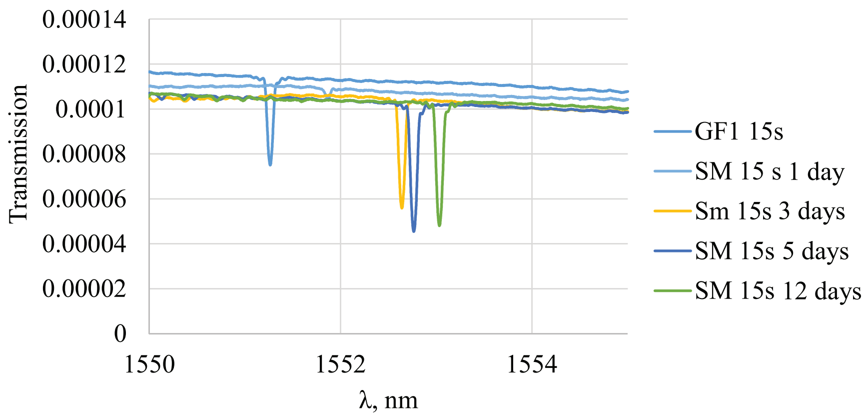

Fig. 7. Fiber Bragg Grating transmission spectrum recorded for 15 s in GF1 and single mode optical fibers

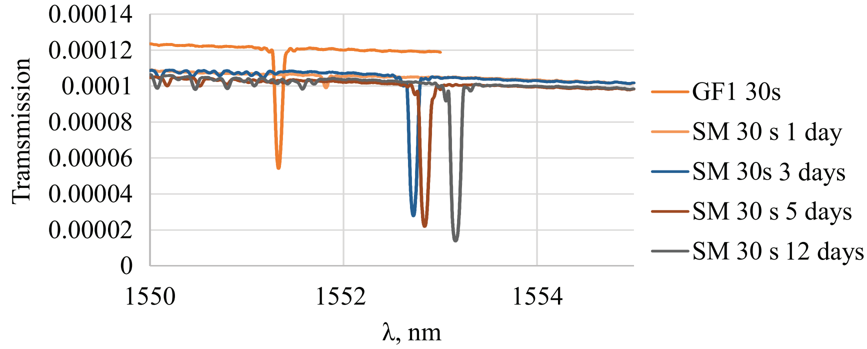

Fig. 8. Spectrum of Fiber Bragg Grating transmission recorded for 30 s. in GF1 and single mode optical fibers

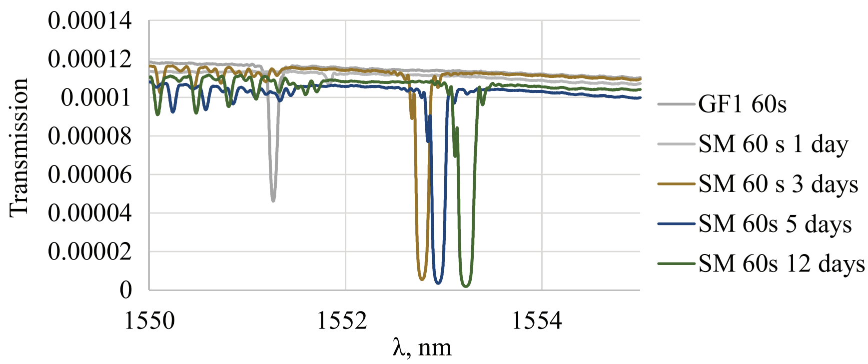

Fig. 9. Transmission spectrum of the Fiber Bragg Grating recorded for 60 s in GF1 and single mode optical fibers

Table 3

Attributes of Cleveland dataset

GF1 15 s		SM 15 s 3 days		SM 15 s 5 days		Sm 15 s 12 days	
λ, nm	dB	λ, nm	dB	λ, nm	dB	λ, nm	dB
1550	1.17E-04	1550	0.000105	1550	0.0001069	1550	0.0001059
1550.5	1.15E-04	1550.5	0.0001048	1550.5	0.0001052	1550.5	0.0001058
1551	1.15E-04	1551	0.0001047	1551	0.0001049	1551	0.000104
1551.1	1.14E-04	1551.1	0.0001044	1551.1	0.0001047	1551.1	0.0001048
1552	1.13E-04	1552	0.0001055	1552	0.0001035	1552	0.0001034
1552.5	1.12E-04	1552.5	0.0001047	1552.5	0.0001028	1552.5	0.0001032
1553	1.12E-04	1553	0.0001037	1553	0.0001016	1553	0.00007052
1553.5	1.11E-04	1553.5	0.0001018	1553.5	0.0001012	1553.5	0.0001028
1554	1.10E-04	1554	0.0001004	1554	0.0001005	1554	0.0001024
1554.5	1.08E-04	1554.5	0.00009924	1554.5	0.00009929	1554.5	0.0001011
1555	1.08E-04	1555	0.00009889	1555	0.00009849	1555	0.0001003

Table 4

Data obtained when exposed to UV radiation on OF for 30 seconds

GF1 30 sec		SM 30 sec 3 days		SM 30 sec 5 days		SM 30 sec 12 days	
λ, nm	dB	λ, nm	dB	λ, nm	dB	λ, nm	dB
1550	0.0001234	1550	0.000109	1550	0.000105	1550	0.000106
1550.5	0.0001221	1550.5	0.000109	1550.5	0.000101	1550.5	0.000102
1551	0.0001219	1551	0.000108	1551	0.000102	1551	0.000103
1551.5	0.0001197	1552	0.000107	1552	0.000102	1552	0.000104
1552	0.00012	1552.5	0.000106	1552.5	0.000101	1552.5	0.000103
1552.5	0.0001195	1553	0.000104	1553	9.79E-05	1553	0.0001
1553	0.0001187	1553.5	0.000104	1553.5	0.0001	1553.5	0.0001
1554	0	1554	0.000103	1554	9.97E-05	1554	1E-04
1554.5	0	1554.5	0.000102	1554.5	9.84E-05	1554.5	9.92E-05
1555	0	1555	0.000102	1555	9.82E-05	1555	9.85E-05

Table 5

Data obtained when exposed to UV radiation on OF for 30 seconds

GF1 60 sec		SM 60 sec 3 days		SM 60 sec 5 days		SM 60 sec 12 days	
λ, nm	dB	λ, nm	dB	λ, nm	dB	λ, nm	dB
1550	0.000118	1550	0.000116	1550	0.000108	1550	0.00011
1550.5	0.000117	1550.5	0.000113	1550.5	0.000106	1550.5	9.59E-05
1551	0.000117	1551	0.000114	1551	0.000103	1551	0.000109
1552	0.000115	1552	0.000114	1552	0.000106	1552	0.000108
1552.5	0.000115	1552.5	0.000113	1552.5	0.000105	1552.5	0.000108
1553	0.000114	1553	0.000112	1553	2.09E-05	1553	0.000107
1553.5	0.000113	1553.5	0.000112	1553.5	0.000104	1553.5	0.000107
1554	0.000112	1554	0.000112	1554	0.000103	1554	0.000105
1554.5	0.000111	1554.5	0.00011	1554.5	0.000101	1554.5	0.000104
1555	0.00011	1555	0.00011	1555	9.99E-05	1555	0.000104

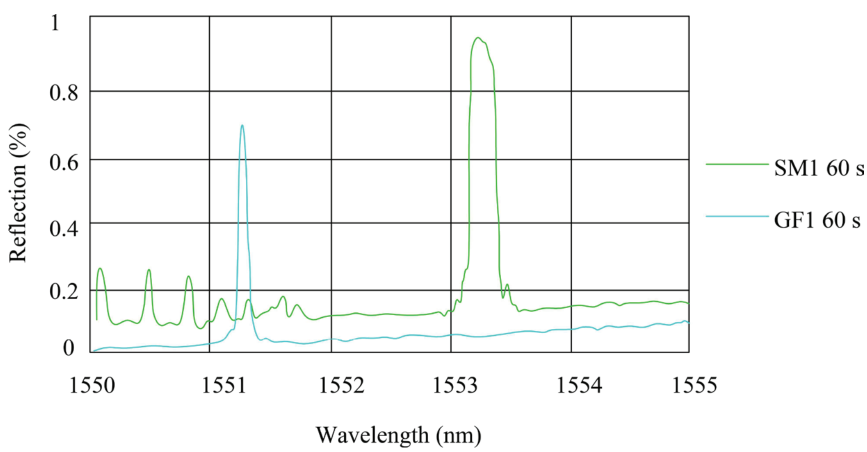

Fig. 10. Transmission and reflection spectrum of FBG recorded during 60 s in GF1 and SM OPTIC fibers

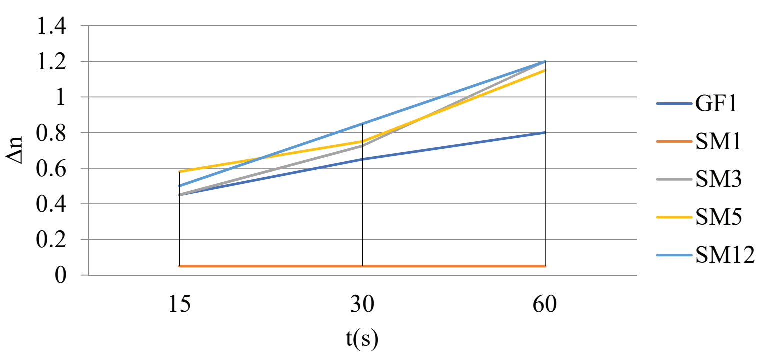

Fig. 11. Modulation of the RI refractive index during the duration of exposure to UV Ultraviolet radiation

The amount of wavelength shift depends on several factors, such as the reflectivity of the lattice, the concentration of hydrogen in the fiber, and the dosage of UV radiation exposure.

It is known that in order to increase the photosensitivity of the fiber, the concentration of GeO_2 in its core is increased to 12, 16 and 18 mol. %. The method of alloying blanks for extracting optical fiber with germanium dioxide (GeO_2) is the simplest, most effective and gives a constant time increment of photosensitivity.

Modulated index changes of more than 1.2 were obtained based on the transmission depth of a uniform lattice. Without a hydrogen load, the lattice recorded in a fiber doped with germanium oxide (GeO_2) under similar exposure conditions has a change in the modulation amplitude of the induced refractive index from 0.45 to 0.8.

Table 6

Induced refractive index modulation value

Recording time FBG, s	GF1		SM_1		SM_3		SM_5		SM_{12}	
	λ_B, nm	Δn	λ_B, nm	Δn	λ_B, nm	Δn	λ_B, nm	Δn	λ_B, nm	Δn
15	1551.25	0.45	1551.8	0.05	1552.7	0.45	1552.8	0.58	1553.1	0.5
30	1551.25	0.65	1551.8	0.05	1552.75	0.725	1552.85	0.75	1553.25	0.85
60	1551.3	0.8	1551.8	0.05	1552.81	1.2	1552.9	1.15	1553.25	1.2

6. Discussion of the results of the study of comparing the spectral characteristics of fiber Bragg gratings during photosensitization

It is known that to increase the photosensitivity of the fiber, the concentration of GeO_2 in its core is increased to 12, 16 and 18 mol %. The method of alloying blanks for optical fiber extraction with germanium dioxide (GeO_2) is the simplest, most effective and gives a time-invariable photosensitivity increment coefficient.

The disadvantages of the chosen method include an increase in the linear optical losses of the light guide. For example, for a birefringent OM used in the work with a straining elliptical shell with a GeO_2 content of 16 mol. % losses are about 18 dB/km at a wavelength of 1550 nm.

The wavelength also shifts towards a longer wavelength during exposure. The shift of the Bragg wavelength increased linearly over time, and the growth of the Bragg reflection became saturated after a certain exposure time. In addition, some limited experiments have shown that there is a correlation between the Bragg wavelength shift rate and the phase mask used for exposure. This suggests that the optical quality of the phase mask may contribute to the controllability of the Bragg wavelength.

The disadvantages of the chosen method include an increase in linear optical losses of the light guide. For example, for a birefringent OHM used in working with a deformable elliptical shell with a GeO_2 content of 16 mol. % losses are about 18 dB/km at a wavelength of 1550 nm.

In this paper, it is shown that strong and stable photosensitivity can be fixed in standard single-mode optical fibers.

The wavelength also shifts towards a longer wavelength during exposure. The Bragg wavelength shift increased linearly over time, and the growth of the Bragg reflection became saturated after a certain exposure time. In addition, some limited experiments have shown that there is a correlation between the Bragg wavelength shift rate and the phase mask used for exposure. Table 6 shows the results of studies that show that exposure to UV radiation with the presence of hydrogen creates a very large and persistent increase in the photosensitivity of the fiber. The exposure time in 60 s of a Bragg fiber lattice pre-saturated in hydrogen turned out to be an effective modulation amplitude of the induced refractive index Δn=1.2 with a refractive index neff=1.438 and the use of a phase mask with a constant period of 1080 nm. While the amplitude of the modulation of the induced refractive index of the FBG recorded in the OM with an admixture of GeO_2 without loading in hydrogen is 0.8 at neff=1.438. This proves that the VBR recorded in the S, saturated in hydrogen in advance for 12 days, are characterized by increased photosensitivity. And also, the greater the modulation depth of the PP inside the Bragg fiber lattice, the greater the reflection coefficient of the FBG. This suggests that the optical quality of the phase mask may contribute to the controllability of the Bragg wavelength.

The magnitude of the wavelength shift depends on several factors, such as the reflectivity of the lattice, the concentration of hydrogen in the fiber and the dosage of exposure to ultraviolet radiation.

7. Conclusions

1. It has been proven that an increase in the photosensitivity of optical fibers, as well as a strong and stable photosensitivity can be recorded in standard single-mode optical fibers sensitized with hydrogen and laser radiation of 193 nm.

2. According to the experimental data, a comparison of the spectral characteristics of fiber Bragg gratings proved that photosensitization becomes saturated when the *S* is exposed for 3 and 12 days with exposure to 60 s and moves deeper into the core, which ultimately leads to uniform sensitization of the core of the VBR. However, when the S is saturated for 3 days, the wavelength of the Bragg resonance is 1552.8 nm. Consequently, the high photosensitivity is provided by the VBR created in an optical fiber with a saturation of 12 days, since the wavelength of the Bragg resonance was 1553.2 nm.

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