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Issue Article

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FEATURES OF MANUFACTURING FIBER BRAGG GRATINGS

***Abstract**: Features of manufacturing fiber Bragg gratings, which are sensors based on fiber Bragg gratings. The types of Bragg lattices are considered, i.e. straight homogeneous lattices, lattices with variable periods, lattices with a long period, oblique lattices.*

***Key words**: Fiber Bragg gratings, reflection spectrum, sensors, period.*
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Introduction

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One of the most commonly used fiber-optic sensors are sensors based on fiber-Bragg gratings. The gratings reflect a light signal, the spectral characteristic of which (wavelength) shifts along with the change in the measured parameter (temperature).

In the manufacture of gratings, an area with a periodic change in the refractive index is created inside the core, and this area is directly called the VBR. A fiber Bragg lattice is a section of an optical fiber in the core of which the refractive index periodically changes in the longitudinal direction], which is shown in Figure 1 [1].

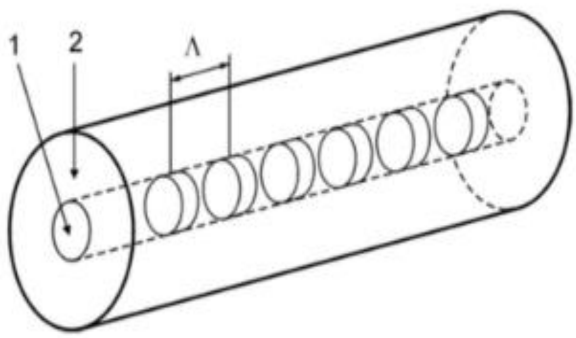

Figure 1. Fiber-bragg lattice where:
1- is the core, 2 - is the cloak,
λ - is the lattice period

The reflection spectrum of the fiber bragg lattice, depending on the wavelength, is shown in figure 2.

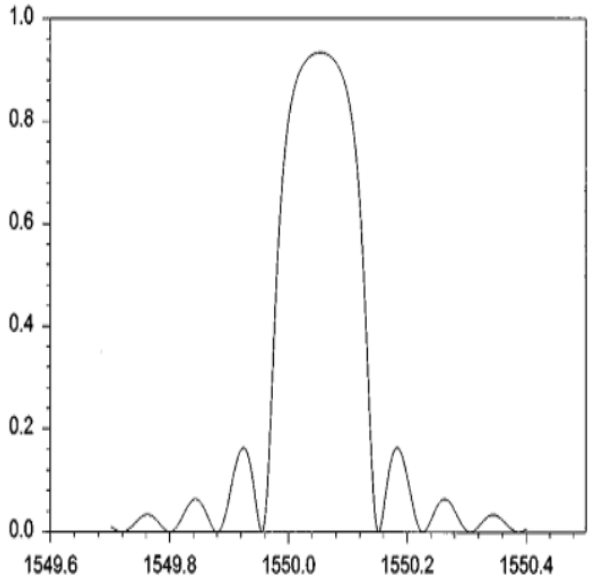

Figure 2. The reflection spectrum

Straight homogeneous gratings are a distributed bragg reflector formed in the light-carrying core of an optical fiber. straight homogeneous gratings have a narrow reflection spectrum, are used in fiber lasers, fiber-optic sensors, to stabilize and change the wavelength of lasers and laser diodes, etc. (fig.3).

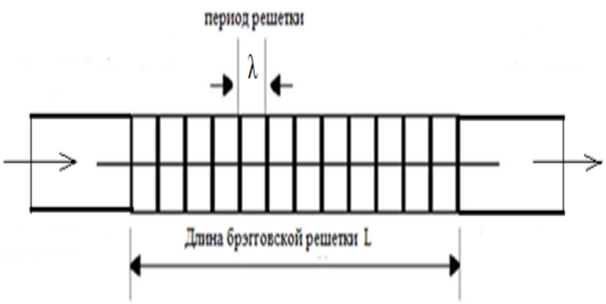

Figure 3. Structure of a straight homogeneous lattice

A chirped bragg lattice is called a bragg lattice, which has a period dependence along the direction of light propagation (chirp). Different wavelengths are reflected from the bbr at different depths having the corresponding period. the most common chirped bragg gratings with linear chirp. Thirped gratings are mainly used to compensate for dispersion [2]. The production of chirped bragg gratings (cbr) consists of the narrowing and bending of the optical fiber during recording and the linear stretching of the phase mask obtained when it is heated. phase masks with variable pitch are also used in the production of chirped bragg gratings. in lattices, chirp denotes an increase or decrease in the lattice period, and this change in the length of the period is most often linear. The cross-section of the structure formed on the fiber core is shown in figure 4.

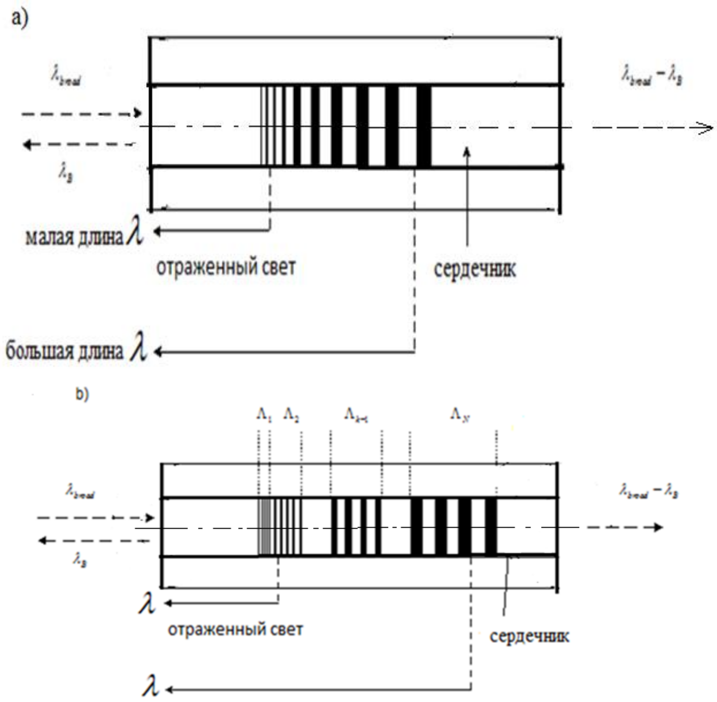

Figure 4. The structure of the chirped bragg lattice (cbr):
a) chirping of the bragg lattice,
b) cascade chirped lattice

The lattices shown in figure 4 can be obtained using fixed changes in the lattice period λ or by changing the refractive index in the core. Such a lattice can be used for different wavelengths. In chirped lattices, the frequency resonance is a linear function symmetric along the lattice [3]. Individual frequencies are reflected in different places of the grid. This results in different delay times. a temporary extension of the pulse is possible (figure 5).

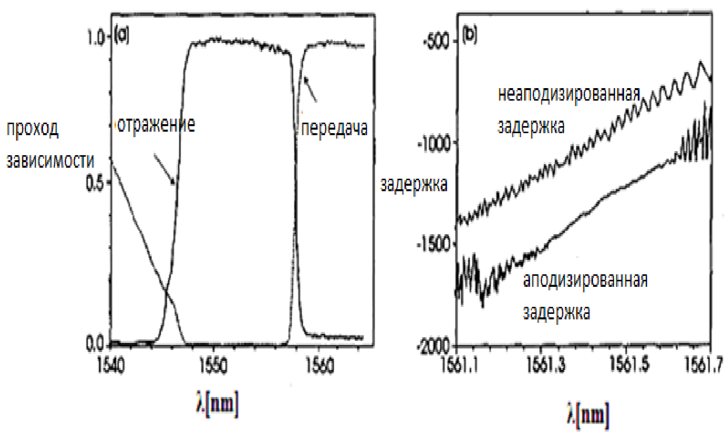

Figure 5. Characteristics of a typical bbr grating
a) transmission reflection profile,
b) apodized and non-apodized group delay

Lattices with a long period are a special type of bragg lattices with a period of microns. they combine the main mode with the upper layer modes propagating in the same direction.

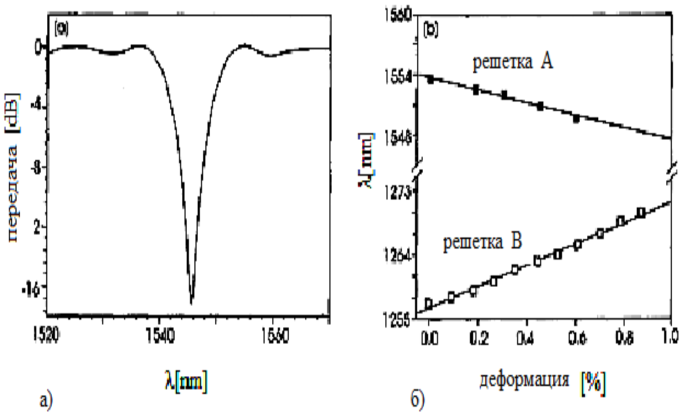

Figure 6. Characteristics of a lattice with a long period:
a) long-term transmission spectrum of the lattice,
b) the effect of deformation of two different gratings

In addition, fiber-optic amplifiers with light pumps are used in telecommunication systems [4]. They reduce the performance of the entire system by increasing the noise level by using wavelengths that have not been absorbed. This can be avoided by using chirped gratings that reject unoccupied wavelengths and leave only those that are really needed. this reduces the noise level. Such gratings can be used in the design of erbium optical amplifiers [5]. Chirped gratings are increasingly used as elements in telecommunication systems.

The technology of creating distributed fiber-optic phase interferometric sensors based on Bragg gratings requires recording arrays of gratings with specified reflection coefficients and spectrum width at half-height during the extraction of a fiber fiber [6].

It is known that type I Bragg fiber gratings can be recorded with almost any reflection coefficient and spectrum width at half-height, however, this requires the use of recording methods with a long exposure (10-20 min) [7], which cannot be done during the extraction of optical fiber. The use of type II gratings makes it possible to implement the technology of single-pulse recording of Bragg gratings with reflection coefficients up to 100% and the width of the reflection peak at half-height up to 1 nm [4]. However, type II gratings are characterized by a sharp dependence of the induced modulation of the refractive index in an optical fiber on the energy density in a laser pulse. This feature complicates obtaining a grating with the desired reflection coefficient, in addition, recording a type II grating into a fiber reduces the mechanical strength of the fiber fiber [8].

Therefore, in order to create a sensitive element of a fiber-optic FEED with the required ratio of the reflection coefficients of lattice pairs and a sufficient spectrum width at half-height, a method for obtaining chirped fiber Bragg gratings with a discretely varying period during optical fiber extraction was proposed and tested [4]. The main purpose of the work was to test the applicability of such gratings in distributed fiber-optic phase interferometric sensors. In order to achieve the goal of the work, experimental studies of the influence of various external influences on the spectral characteristics of Bragg gratings were carried out.

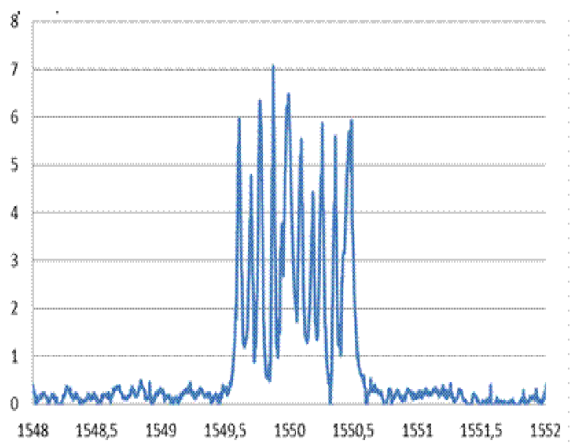

Figure 7. The spectrum of a fiber Bragg lattice with a discretely varying period

The effect of longitudinal mechanical stress. Using a device that creates a tension corresponding to a given value of the applied force and an optical spectrum analyzer, the effect of fiber tension on the displacement of the central wavelength was checked. The experiment was carried out at applied force values from 4 to 20 N. The limit values are determined by the technical characteristics and capabilities of the device. A step of 1 N is enough to determine the dependence. The light source and the spectroanalyzer were connected through a splitter to a grid, which, in turn, was located in the area of the light guide, to which a mechanical longitudinal voltage was applied using a specialized apparatus. Based on the results, graphs were constructed, dependencies were obtained.

The effect of temperature exposure. It is known that a noticeable degradation of gratings, the formation of which is due to the electrostriction mechanism, is observed already at 200-300 °C [4]. In addition, a change in temperature leads to a change in the wavelength of the Bragg resonance, which may interfere with the correct operation of interferometric sensors. Thus, the task of this experiment was to obtain the dependence of the shift of the Bragg resonance with an increase in temperature, as well as to determine the maximum operating temperatures of the sensor based on type I VBR with a discretely varying period.

To conduct the experiment, a circuit was assembled that included, in addition to a radiation source and a spectroanalyzer, a thermal chamber controlled by a thermostat and an optical power meter. VBR was heated in a thermal chamber to 370 °C, its spectrum was continuously monitored on an optical spectroanalyzer. Figure 2 clearly demonstrates the shift of the spectrum to the long-wavelength region with increasing temperature, as well as a strong decrease in the reflection coefficient at a temperature of the thermal chamber of more than 140 ° C. At a temperature of 280 °C, the spectrum of the grating practically became indistinguishable against the background of the noise of the optical circuit. A number of tests were carried out to determine the thermal stability of the grid. Several samples were successively kept in a thermal chamber for 3 hours and 20 minutes. at different temperatures. Degradation of the gratings was not observed at 100 and 120 °C.

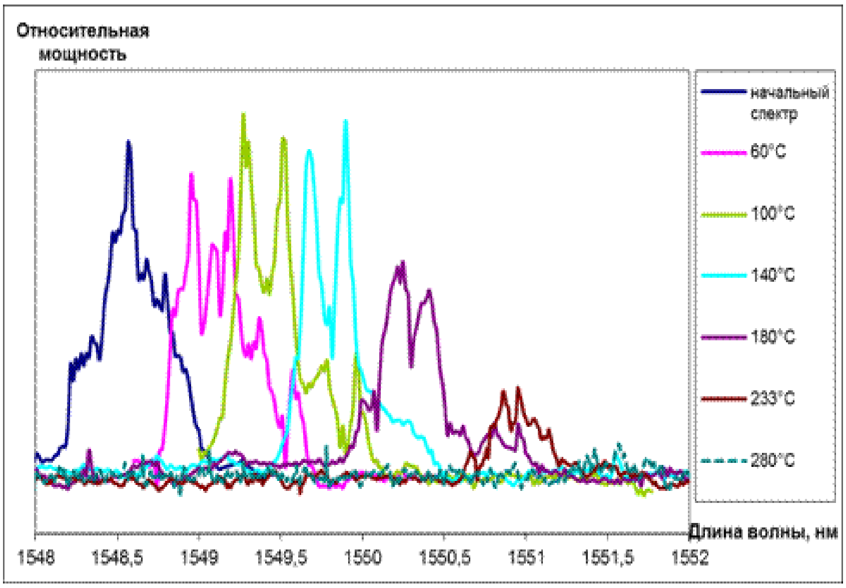

Figure 8. Dependence of the spectrum on temperature

The effect of winding. To study the effect of winding a fiber section with an induced lattice, rigging with different circles was used. The fiber section with the VBR was sequentially wound on diameters from 50 to 5 mm. The spectrogram was taken after winding on each dimeter. The flow of radiation energy between the axes of the birefringent light guide was recorded. At the same time, the spectral distance between the reflection peaks did not change, there were no displacements up to the winding of the light guide to diameters less than 10 mm. After conducting the experiment on relatively large circles, winding on smaller ones occurred with a small effort necessary to overcome the elastic properties of the optical fiber, as a result, a uniform 0.2 nm displacement was observed on the spectrogram, when winding on the smallest diameter, the displacement was 0.4 nm. The change in the localization of the peaks was associated with the applied tensile force, as a result of which the quartz glass was stretched and the displacement characteristic of mechanical stretching occurred. The experiment allowed us to establish that for fiber gratings with a length of 100 mm, winding even on small diameters does not significantly affect the reflection spectrum of the lattice.

Dependence on the state of the introduced polarization. The dependence of the reflection coefficient of chirped fiber Bragg gratings with a discretely varying period on the state of polarization introduced into a birefringent light guide was investigated. To test this dependence, a scheme was assembled, the key elements of which are a polarization controller and an extinction meter. 5 test samples were alternately included in the scheme. The difference in reflected energy from different polarization states did not exceed 2 percent. The results obtained allow us to judge the independence of the VBR with a discretely varying period from the state of the introduced polarization.

In the course of the work, various factors influencing the spectral characteristics of chirped fiber Bragg gratings with a discretely varying period were investigated. The number of sections of a chirped VBR with a discretely varying period is theoretically calculated to obtain a quasi-continuous lattice reflection spectrum.

Experiments with the creation of longitudinal mechanical stress have been carried out. The dependence of the displacement of the Bragg resonance on the applied tensile force is obtained. Experiments on thermal effects were carried out. The dependences of the shift of the spectrum of chirped fiber Bragg gratings with a discretely varying period on temperature are obtained. Experiments were conducted to determine the temperature resistance of the tested samples. The dependence of the reflection coefficient of chirped fiber Bragg gratings with a discretely varying period on the state of polarization introduced into a birefringent light guide is investigated. Winding on various diameters is made. The spectra of gratings wound on circles of different sizes are analyzed.

The studied samples have a sufficient half-height spectrum and reflection coefficient for use in phase interferometric sensors. To obtain a quasi-continuous reflection spectrum of the chirped VBR, it is necessary to increase the number of lattice sectors, respectively reducing the angle of displacement of the interferometer mirrors when recording the diffraction structure. Depending on the reflectivity requirements, such a structure can be recorded with the same length or longer [9].

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