About compensation of radiation - induced losses in optical fibers

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Abstract. In article the necessity of developing a method of the compensation of radiation-induced losses in the fiber optic communication lines is substantiated. Reasons of appearance of radiation color centers in the optical fibers are considered. A method of increasing the velocity of the relaxation processes after finishing the γ-radiation influence on the fiber optic communication line is developed. The received results are presented.

1. Introduction
Nowadays high-speed large data exchange is impossible without using the fiber optic communication lines (FOCL). [1-9]. Using of the optic communication lines is carried out in various conditions. [1, 2, 4-6, 8-20]. FOCL and optical methods of information processing [18-30], which are used in lines, are more stable to different influences than other communication lines especially in the presence of electromagnetic interference [31-33]. It allows to use FOCL in radars, satellite systems and other facilities [7-10, 18-22, 34].

Recently, the environmental degradation [35-40] led to the increase of different negative factors influence on the communication lines. The most unpleasant for FOCL is the γ-radiation influence (it changes the properties of the optical fiber) [10, 18-20, 41-45]. The power losses of the optical signal increase, they can be 400 dB/km and higher [41-45]. Losses in the optical fiber, which appeared under the γ-radiation influence, are several hundred times higher than standard losses. It makes the optical fiber unsuitable for data transmission (the standard losses at a wavelength λ=1550 nm and in the operating temperature range from 213 to 338 K are from 0.26 to 0.38 dB/km). Even if the radioactive exposure source is single, the high radiation area around it can be more 100-150 m. It leads to distortion or complete loss of transmitted information over the distance more than 200 km, because the signal level becomes too low and is lost in the noise level. Since some communication lines have long distances, it is impossible to exclude the fact of γ-radiation occurrence in the area of FOCL’s laying.

To this problem is added the fact that the recovery of FOCL parameters takes a lot of time. It is difficult to transmit information during this time. Since the fiber property is not to accumulate radiation in its structure, so it is difficult to establish the determination area after ending the influence [10, 18-20, 41-45].

It should be noted, that the radiation influence doesn’t always lead to structure destruction of the optical fiber. If the radiation dose was low or the exposure time was short, then FOCL will change its properties without the structure destruction It leads to another problem - most of the used fiber optic diagnostic devices are not able to establish the fact of the influence of γ-radiation on the fiber. The optical reflectometers, which are used for determining losses and breaks in the operating communication lines, can’t establish the reason of high increase in losses.
All of this make difficult the operation of trunk fiber optic communication lines. Therefore, the tasks of establishing the fact of the $\gamma$-radiation’s influence on the FOCL and the development of a method of compensating losses are the actual tasks in applied Physics.

2. Experimental setup for research the $\gamma$-radiation influence on losses in fiber

The conducted earlier researches allow to establish the following. The velocity of the relaxation processes, which lead to the color centers destruction, depends on several factors. There are the most significant of them: the optical fiber’s temperature and the optical signal’s power, transmitted via fiber. It was also established, that the velocity of the color centers relaxation (the value of radiation-induced losses $\alpha_s$) also changes according to the type of laser radiation, continuous or pulsed.

The experimental setup, which block diagram is presented on figure 1, is developed for conducting the experiments and developing the methodology of radiation-induced losses compensation.

![Figure 1](image)

**Figure 1.** The block diagram of the experimental setup: 1 - laser transmitting module; 2 - power driver; 3 - polarizer; 4 - optical divider; 5 - optical power meter; 6 - optical adder; 7 - pulsed semiconductor laser; 8 - pulse power driver; 9 - source of $\gamma$ - radiation; 10 - control unit of the source of $\gamma$ - radiation; 11 - optical fiber; 12 - closed volume of a polymeric material; 13 - a device for changing the temperature; 14 - a device for controlling the dose of radiation; 15 - receiving optical module.

To measure losses in this setup, the following classical formula was used:

$$a_s = 10 \frac{\lg P_{\text{out}}}{P_{\text{in}}}$$

where $P_{\text{in}}$ – the power input in to the optical fiber, $P_{\text{out}}$ – the power output from the optical fiber, $L$ – the length of the optical fiber.

The design of the experimental setup was taken into account in determining losses (figure 1). For connecting source, receiver and isolator together with the optical fiber are applied the detachable connections, which have typical losses $\alpha_{pc} = 0.2$ dB. There are 6 such connections. The losses in the optical adder are 0.46 dB. The losses on the optical polarizer are 0.32 dB. Total losses on the connections and adder are 1.98 dB. For registration of low power of the laser radiation at the high losses in the optical fiber the receiving optical module DFDMSH40-16M was used with the power meter. This module has highly sensitive in the wavelength range of 980-1650 nm.
3. Experiment results and discussion.
As an experiment example we used the single-mode optical fiber with a SiO₂ – GeO₂ core (alloying 1.5 %) with an irradiation dose of 100 G. The additional laser radiation with a wavelength of λ = 1310 nm was inputted in the optical fiber with using the multiplexer. We used this irradiation for compensation of radiation-induced losses.

The experimental results of change in relaxation velocity of color centers from the additional laser radiation power are presented at the figure 2. There was full data exchange via FOCL during the experiments. In the first experiment were used the low powers of pulse laser radiation: 0.1, 4.0 и 40 mW. The experiment was during the 10⁶ s.

![Figure 2](image)

**Figure 2.** Dependence of the change in loss αs with time t at a wavelength of λ =1550 nm for a single-mode fiber with a SiO₂ – GeO₂ core (alloyage 1.5 %) at T = 294.2 K. Charts 1, 2, and 3 correspond to different laser radiation powers in mW: 0.1, 4.0, 40.

The analysis of the results shows, that the velocity of relaxation processes increases, when the power of additional radiation increases. The radiation-induced losses in the optical fiber, which was under the γ-radiation influence, compensate after 1000 seconds. Fiber properties become close to initial. The second experiment was conducted with following pulse radiation powers: 0, 200, 400 mW to check the received data and confirm the proposed method efficiency. Other experimental parameters are similar to the parameters of the previous experiment. The results are presented in the figure 3.

![Figure 3](image)

**Figure 3.** The dependence of the change in loss αs with time t at a wavelength of λ =1550 nm for a single-mode fiber with a SiO₂ – GeO₂ core (alloyage 1.5 %) at T = 294.2 K. Charts 1, 2, and 3 correspond to different laser radiation powers in mW: 0, 200, 400.
The received results show that the increase of additional high-power laser radiation increases the velocity of color centers relaxation in the irradiated optical fiber. Initial properties of the optical fiber were recovered. It was done for 100 sec during using the radiation with the power of 20 mW and for 10 seconds during using the radiation with the power of a 40 mW. This method significantly reduces relaxation time. The optical fibers were recovered for $10^8$ seconds without this method. A multiplexer is installed at the output of the optical fiber, in which signals with different $\lambda$ are divided into two channels. In each channel there is a photodetector (one of them is for receiving information, other of them is for controlling irradiation power).

4. Conclusions
The received results show that the developed method is more effective for compensating the radiation-induced losses than previously used. The using the calibration dependencies $\alpha$, from the power of laser radiation and pulse duration, it is possible to establish the fact of the $\gamma$-radiation’s influence on the FOCL. Analysis of the results at the figures 2 and 3 shows, that choosing a certain power of the additional laser radiation it is possible to have a balance of the number of new formed color centers and the number of centers, which were distracted by the influence of the relaxation processes. It allows to transmit through FOCL the optical signal, when it is situated under the $\gamma$-radiation influence.

It was also established that in FOCL the interferences occur, when we use a high-power level of additional laser radiation. Therefore, we will continue our studies to solve this problem.

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