

Conference Paper

Study of Gamma-ray Induced Attenuation of Fluorine-doped Single-mode Radiation Hard Optic Fiber

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Abstract

The paper presents the measurements results of optic fiber's radiation induced attenuation. The approach of optic fiber's radiation test at negative temperatures is introduced. The results of an investigation of the decay of an optical signal during a pulsed electron.

Keywords: radiation hardness, fiber-optic communication, radiation-induced attenuation

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1. Introduction

Increasing the volume of information transfer through communication channels requires constant improvement of the corresponding technical means, among which an important role is played by fiber-optic communication lines.

Fiber-optic communication lines have a number of advantages over metallic wires, for example, they don't require electrical grounding, the dimension, weight and cost of data transmission channels are sharply reduced, reliable galvanic isolation, safety and reliability of data transmission. But there are also drawbacks, in particular, when using fiber-optic communication lines or devices using fiber optical fibers and their modifications, under the conditions of an increased radiation background, the effect of radiation-induced attenuation of the optical signal is manifested.

But also has its drawbacks, the phenomenon of optical signal attenuation in the fiber-optic communication lines. Usually, damping mechanisms are classified into: attenuation caused by absorption, damping from scattering and damping at optical fiber bends, etc. When light waves propagate in fiber-optic media, interactions between photons and atoms of the propagation medium occur. Photons are absorbed

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by the atoms of the optical fiber - this process leads to a decrease in the power of the optical signal through the fiber.

Atoms of optical fiber and impurities are the main factors that influence the increase in attenuation. The collisions of photons with atoms fiber, microscopic changes in the material density and the uneven distribution of the composition or structural defects occurring in the manufacturing process, lead to scattering and consequently in an increase in attenuation.

When using a fiber-optic communication lines or devices that use optical fibers and fiber modifications thereof, under conditions of elevated background radiation effect is manifested radiation-induced attenuation of the optical signal.

Prospects for the use of optical fibers for information transmission and in devices operating under high radiation conditions have caused intensive studies of radiation-optical phenomena in quartz optical fibers, since under the action of ionizing radiation these fibers can lose their capacity [1]. The main reason for the growth of losses is the appearance of color centers in the light-conducting core or in the light-reflecting shell, over which a significant part of the light propagates in single-mode fibers. The nature and amount of color centers are largely dependent on the composition of the core and cladding glasses, and a method of manufacturing the fibers.

Currently, the most radiation-resistant optical fibers are considered a pure silica core or a core doped with nitrogen [2]. Conventional "connected" optical fiber with Ge-doped core have an increased radiation-induced attenuation due to the formation of the germanium oxygen-deficient centers (GODCs) [3].

For the application of fiber optic communication lines on board the spacecraft, particle accelerators, or in areas where high levels of electromagnetic radiation prevails, the studying of optical fibers radiation hardness and determining the signal attenuation from the effects of ionizing radiation becomes an important task [4, 5].

2. Experiments

The aim of the work is an experimental study of the response to the exposure of gamma radiation of a single-mode radiation-resistant fluorine-doped optical fiber. Also, tests of pulsed electron radiation reaction were conducted.

The object of the research was optical fiber with a length of $L \approx 500\text{m}$, with non-radiation-resistant fiber-optic pigtailed with FC / UPC connectors.

The first stage of studies has been conducted on the isotope facility with ^{137}Cs isotope. The irradiation time was 790 hours; the dose rate was 0.27 rad / s. The total absorbed dose was 795 krad. During the irradiation, the optical power was monitored when the signal passed through the fiber. The results of the control are shown in Fig. 1. As can be seen from the figure, the magnitude of the optical signal attenuation increased by 1 dBm for a wavelength of 1310 nm and by 1.8 dBm for 1550 nm.

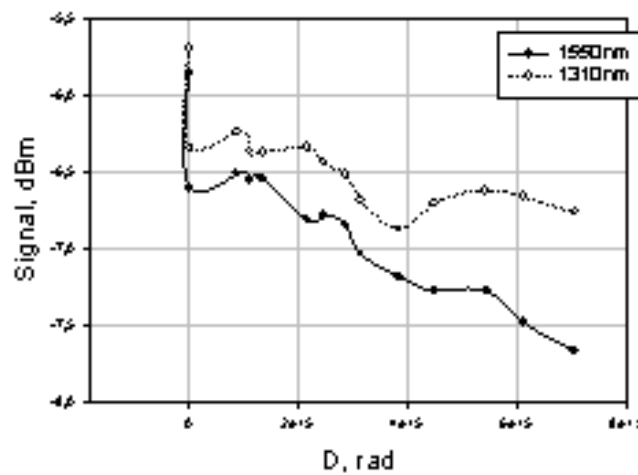


Figure 1: Dependence of the optical signal at the fiber output from the total ionizing dose for wavelengths of 1550 nm and 1310 nm at constant input illumination of -5.0 dBm.

The second stage was the testing and development of the method for setting a low ambient temperature during the irradiation of the optical fiber on the electron accelerator U-31/33, which operates in the bremsstrahlung (deceleration radiation) mode. The layout of optical fiber positioning is shown on Figure 2.

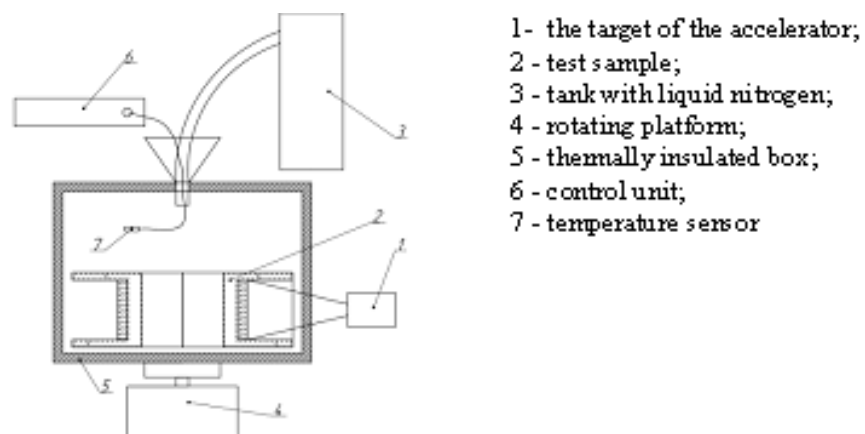


Figure 2: Scheme of optical fiber positioning during studies at electron accelerator in the bremsstrahlung regime.

The temperature -60°C is set by the SZTM-0401 (cooling with nitrogen vapors entering the tube into a heat-insulated box). Uniform irradiation of the sample is achieved by rotating the sample around its axis.

The exposure time was 5400 s. with a dose rate 0.81 rad / s . The total ionizing dose was 4.4 krad. During pauses of irradiation, the optical power was measured when the signal passed through the optical fiber. As can be seen from Fig. 3, the magnitude of the optical attenuation increased approximately 4.3 dBm for a wavelength of 1310 nm and 4.5 dBm for a wavelength of 1550 nm.

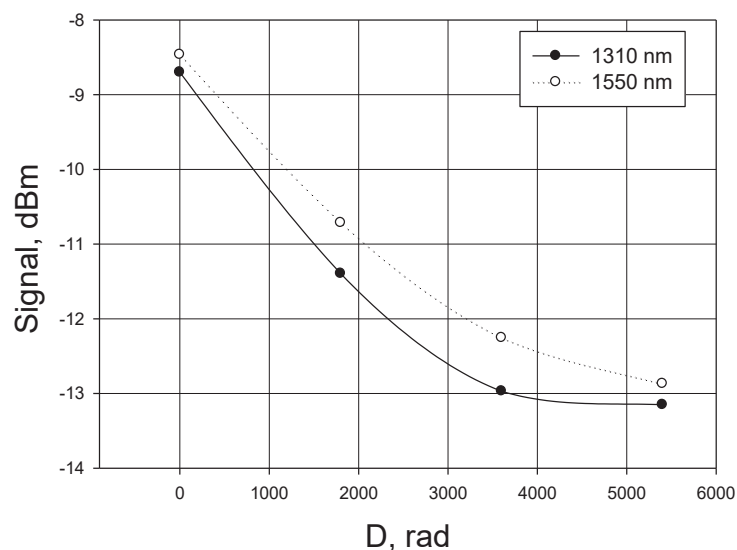


Figure 3: Dependence of the power of the optical signal at the output of the optical fiber from the accumulated dose with a constant input illumination of -5.0 dBm and an ambient temperature of -60°C .

After turning off the exposure and heating to room temperature, the fiber attenuation value returned to the initial value (Figure 4).

On the third phase the studies were carried out on a pulsed electron accelerator "ARSA-2". The fiber positioning scheme is shown in Figure 5. This design allows radiation to be exposed to optical fibers at different distances and to measure the amount of attenuation induced by the pulse.

As seen in Figure 6, depending on the dose per pulse increased attenuation of the optical signal in the fiber. And then, within a few seconds, annealing occurred and the value of the attenuation value returned to the original value.

3. Results and discussion

As a result of fiber research and studies, the following is established:

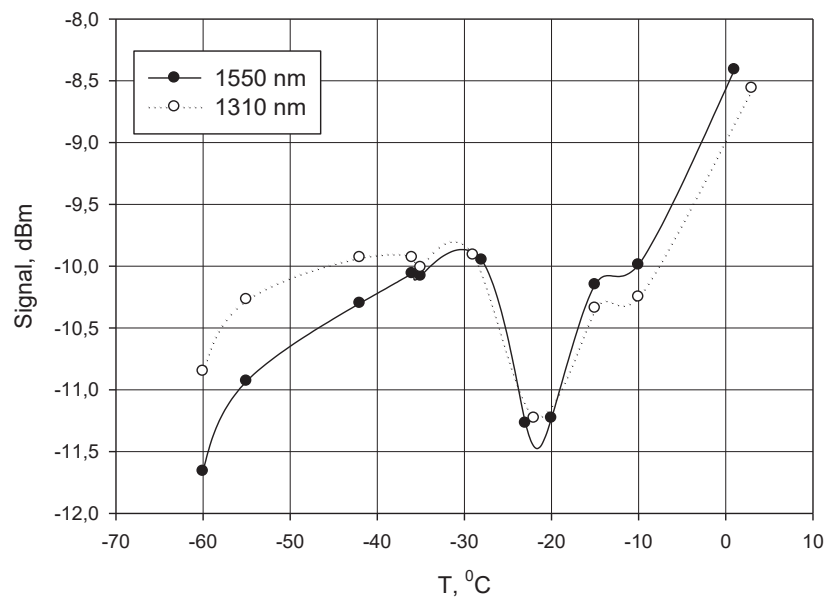


Figure 4: A plot of the power of the optical signal output fiber depending on the temperature.

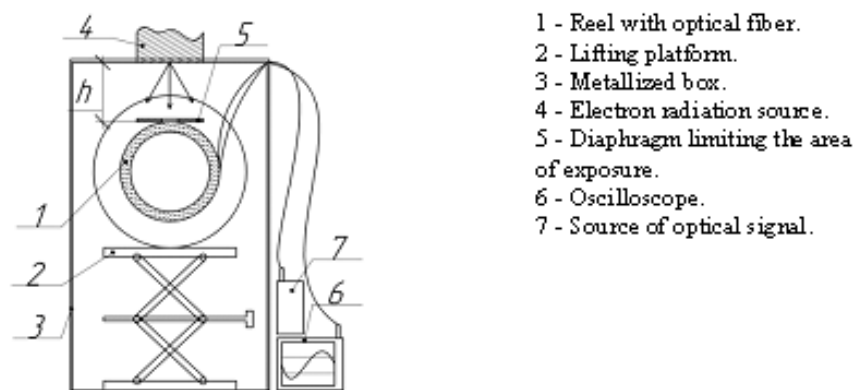


Figure 5: Scheme of installation in the study on the pulse accelerator "ARSA".

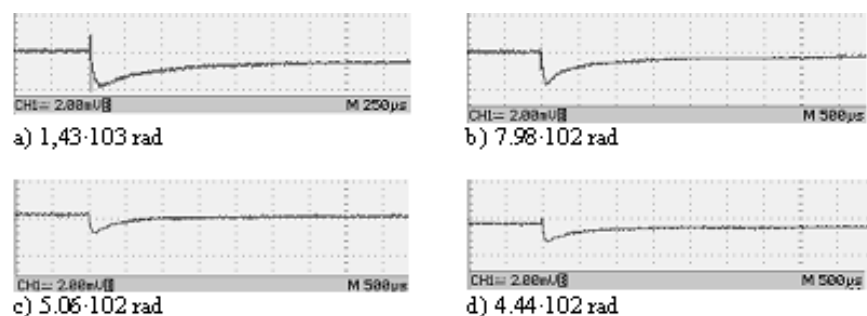


Figure 6: Waveforms reaction of radiation-induced attenuation at the electron radiation pulse the magnitude of the accumulated dose.

During studies on ^{137}Cs isotope facility the increase of radiation-induced losses was observed. However, due to the presence of pigtails of non-radhard optical fibers with

connectors, it is impossible to draw unambiguous conclusions on the radiation resistance of optical fibers.

In studies with an electron accelerator operating in the bremsstrahlung generation mode at minus 60°C, an increase in radiation-induced losses was observed. However, with an increase in the temperature up to room temperature, this value returned to the initial.

When exposed to electron radiation pulse momentary attenuation of the optical signal was observed.

4. Conclusions

The test sample showed a high index of radiation resistance. When exposed to radiation, a slight attenuation was observed, which is not critical, and the subsequent relatively rapid annealing. In the future, it is planned to conduct tests on radiation-induced damping. Also, in order to reduce the effect of photo-ignition, with 316 μW (-5 dBm) to 1 μW (-30 dBm).

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