ANNOTATION

on the dissertation of the scientific degree of PhD in specialty 6D071900 – Radiotechnics, electronics and telecommunications

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Investigation of simulated Brillouin scattering in the singlemode optical fiber at wavelengths 1.31μm and 1.55μm

Actuality of the work

Nowadays the scale of the use of modern fiber-optic communication system is significantly expanded, and possibilities to distribute information to each subscriber's devices via fiber as well as the highway networks, is growing every day. As a result, the volume of information distributed by the highway networks is dramatically increasing. However, the effects of various physical phenomena are limiting the capability of the highway fiber-optic networks to distribute information, so the amount of disseminated information is limited. Most of these limitations depend directly on physical properties and chemical structure of the fiber. The mentioned limitations in data propagation occurred due to effects become known in the beginning of XX-th century such as simulated Brllouin scattering (SBS), Rayleigh scattering, Mie scattering, simulated Raman scattering, Bragg effect; and as the mankind used efficiently those effects for its own purposes it became possible to create devices detecting the external effects (level of external pressure, temperature effects, etc) occurring in the fiber.

By means of SBS effect, some specially designed sensors are able to find the accurate location of errors occurred along the fiber. By sending the probe signal using SBS effect, all the modern reflectometers identify the location of the error by detection of amplification of SBS back-scattering in the error location in the result of data signals interaction.

A new wave of modern technologies development is implementation of DWDM technology and solution of the problem on increasing the density of data propagated along the optical fiber. However, it is still impossible to increase data density by SBS effect along a single mode up to the required level. SBS effect became known in sixties of XX-th century, and due to the rapid increase of data density its real effect and problems are re-considered with enthusiasm. The reason is the fact that modern upgraded optical fibers allow to propagate data by means of laser sources with several modes.

There is still no solution to the problem of increasing the data intensity above the values of 15 dBm for 1310 nm and 27 dBm for 1550 nm which are commonly accepted as SBS threshold in the referenced literature. The problem of SBS threshold is not solved yet, date density increased only in an extensive way, by increasing the number of fibers. Investigation of the SBS effects, providing a new method for determining the SBS threshold, determination of dependency of SBS

effect on the modulation frequency and the search for solutions to the challenges ahead can be considered as main objectives of the work.

At research of optical fiber, particularly at research of ways of the mainline optical spread, many different non-linear effects start to contribute. Among them, methods of segregation and research of SBS methods are quite developed. We can indicate the mentioned above bases of research of wave energies and spectral characteristics as special features of scientific works devoted to SBS effects. The Reflectometer device based on SBS effect is widely used in order to register and use efficiently SBS effect among the works on revealing, registering and suppressing the nonlinear effects in the mainline ways of optical spread within the Republic of Kazakhstan. Taking into account the differences of contributions of nonlinear effects in the mainline waveguides, and particularly and mainly of SBS effects, in comparison with nonlinear effects in the optical waveguides in the buildings within the city, protection from SBS effects is done by limiting the maximum value of energy of rays source for 1310 nm as 15 dB, and for 1550 nm as 27 dB.

About 100 papers were considered as a result of review of literature on scientific works devoted to the research of SBS effect, and some main directions were identified:

- Works on identification of SBS effect among the non-linear optical phenomena in the optical fiber;
- Creation of Brillouin sensors and filters by use of SBS effects and regarding the special features of their use;
- Regarding the new methods of determining the SBS threshold;
- Research of SBS effects occurred due to optical properties of light sources – lasers and light diods;
- Regarding the building of mathematical models for research of SBS effects;

As mentioned above directions deal with the considered research, more attention was paid to them.

One of the points of literature review, which is worth to indicate, is that all the other authors refer in their papers to the scientific papers of G. Agrawal who is the USA specialist in optical fiber. For example, in monography works of European and Russian scientists such as William Daisy, S.A. Bulgakov where they consider nonlinear processes in the optical fibers, they directly refer to G. Agrawal. Correspondingly, in works on search for mathematical model for interpreting the data obtained in results of laboratory works, it was revealed in the result of computing that G. Agrawal's mathematical model interprets effectively the most part of laboratory measurements.

The basic structure of scientific laboratories is similar in all the scientific works directed to research of properties of optical fibers. As all the laboratories register spectral, energetic and other characteristics of the light ray entering the optical fiber, ray exiting the fiber from the other end, and the back-scattered ray, the methods of comparing them are similar.

The issue addressed in the paper is research of SBS effects by means of two optical radiation sources of wavelength 1,31μm and 1,55μm in the single mode fiber-optic communication network.

As upper limits of intensity and energy of incoming signals of all the main fiber-optic networks depend on SBS effect, methods to reduce the impact of this phenomenon is being searched. The main purpose of this work is to gather more information on effect of conditions and external effects on this phenomenon and to make the appropriate conclusion by results of the research.

The purpose of the work

Investigation of simulated Brillouin scattering in the singlemode optical fiber at wavelengths 1.31μm and 1.55μm

Achievement of the following objectives during the research was planned:

1. To review available scientific works corresponding to the theme of the scientific work;

2. To study the specifics of interaction of single mode optical fibers of several different wavelengths;

3. To carry out practical studies of SBS by the pulse energy measurement during passing individually and jointly through the wave guide and scatterion of radiation of wavelengths 1310nm and 1550nm and determination of dependence of energy values on modulation frequency;

4. To provide a new method for determining the threshold of SBS by comparison of the results of practical studies by developing a mathematical model.

Novelty of the scientific work

1. It was observed that simulated Brillouin scattering of optical rays of wavelengths 1.31μm and 1.55μm in one direction in the singlemode optical fiber and the back scattered Stoks rays are decreased;

2. Patterns of dependence of energy of back scattered and passed rays of the signals sent at each of two wavelengths, individually and jointly, on the change in the modulation frequency were revealed.

3. Two waves obtained in the results of the research are gathered and interacted in the waveguide, so the decrease of SBS threshold of rays, back scattered and passed in the result of such interaction, was observed, and by means of comparisons using mathematical modeling it was shown that contribution of SBS threshold is high.

4. The values obtained in practical studies and mathematical models showed the highest comparison accuracy of the results obtained. The practical measurements values in the points where nonlinear processes start for each wave individually shows the correct results when checked by G.Agraval's mathematical model.

Methods of the research

In order to fulfil the objectives: the results obtained in the experimental research were checked by mathematical modeling.

Statements to defend:

1. SBS threshold values observed at sources with wavelengths 1310nm and 1550nm are lower than SBS threshold values observed at distribution of radiation of these two sources through one channel.

2. It was proved that effective threshold values of energies of back scattered and passed rays at distribution of two waves through one channel are shown at increase of modulation frequency.

3. Based on the experimental results, the high contribution of SBS effect can be detected in determining of nonlinear effects in long wave guides.

4. Increase in the SBS threshold by double wave distribution is due to the failure to achieve SBS threshold at individual distribution of two waves.

The first section covers the review of scientific literature regarding the SBS effect, especially regarding the SBS effect, which occurs in the result of interaction of two rays in the single mode optical fiber. The main processes taking place in the devices designed to use SBS effect were considered. The main parameters of SBS effect were considered, data is given on features and relation to SBS of self-phase modulation, cross-phase modulation, simulated Raman scattering. The objective of review of such works is to prove that the work is not repeated and to state the novelty of the work.

The second section considers methods of determining the SBS threshold. Also it deals with issues of determining the SBS effect contribution to main lines. Within the investigation of non-linear effects along the optical fiber, the review of scientific literature studying the dependence of external effects of SBS threshold such as temperature, pressure was done. It is revealed in those papers that coefficient of SBS effect raising and coefficients of signals attenuation is directly proportional to increase of external deformation and increase of temperature. As well, dependence of change of value of the emergent rays spectrum width and the frequency of phase modulation on methods of determining the SBS threshold and increase of its value.

By using the equation of SBS threshold power $P_{SBS,}$ the dependency of the SBS threshold power oscillations on the spectral width of rays source was determined. Matlab software was used for computing the value of SBS threshold power and for construction of diagrams.

It was observed that the value of SBS threshold power increases with increase of spectral width of rays source that was computed from equation deducted for wavelengths 1550nm and 1310 nm.

The third section gives explanations for performances of laboratory equipment required for carrying out the researches in the scientific laboratory for investigation of SBS effect.

The fourth section interprets the results of laboratory works by direct processing in order to give the analytical explanation. The main result of the laboratory works is finding the mathematical model types for explaining the fact of decrease of SBS threshold when rays of wavelength 1310 nm and 1550 nm at the same time pass through the fiber and processing the computer model in the Matlab platform.

Approbation of the work

Approbation of the work was done by presenting the research results in the proceedings of the following conferences:

II International scientific-practical conference «Information and telecommunication technologies: education, science and practice» (Almaty, 2015);

International scientific-practical conference «Modern information and telecommunication technologies» (Kiev, 2015);

International scientific conference of students and young scientists «Farabi world» (Almaty, 2016).

International scientific-practical conference «Innovational mechanisms of solving problems of scientific development» (Ufa, Russia, 2016);

International scientific-practical conference «New science: up-to-date situation and development ways» (Orenburg, Russia, 2016);

International scientific-practical conference «Modern conditions of interaction of science and technology» (Kazan, Russia, 2017).

Publications

13 articles were published on results of the work regarding the Thesis theme, where: 4- at scientific publishing houses of Ministry f Education and Science of RK, 1- in the journal, included to the Thomson Reuters base, 6 at international conferences, including 4 conferences abroad, 1 conference paper, 1 – included to Scopus base.

Scientific and practical value

The scientific value of the results of the dissertation is proposition of ways for increasing the conductivity by means of laying simultaneously the double wave of transparency corresponding to that of the window along the optical fiber.

The practical value of the research results is reliability improvement by means of decrease of nonlinear effects in the operation of the fiber optical communication lines and the results obtained in the dissertation work are based on the adoption acts.

Reliability and reasonability of results

The reliability and reasonability of results of the dissertation work is in the fact that all the conducted experimental researches correspond to up-to-date scientific theoretical methods used for optical fibers.