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Evaluation of the Reliability of Laser Diodes of the DFB Type Based on the Method of Automatic Current Control

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ABSTRACT: In this article, the process of evaluating the reliability of DFB laser diodes used in optical transport networks, the channels of which are separated by wavelength, is carried out. In this case, several DFB-type lasers are subjected to high-temperature tests. Changes in their parameters and characteristics during high-temperature tests are investigated.

KEY WORDS: Laser diode, automatic current control, optical transport networks, optical network reliability, radiation power, laser working current.

I. INTRODUCTION

During today's SARS-COV-2 pandemic, many areas of human life have become dependent on telecommunications networks. That is, education, medicine and many other fields rely on telecommunication networks to organize their activities. This, in turn, leads to an increase in the requirements for the parameters and characteristics of telecommunication networks. Today there is no technology that can compete with DWDM technology in the organization of high-capacity optical transport networks. Certainly from the point of view of application in work.

II. RELATED WORK

To increase the number of channels in DWDM networks, it is necessary to further reduce the protection band between channels in it, for example, to 12.5 GHz. Very high demands are placed on the spectral width and emitting resistance of laser diodes used in the manufacture of such optical channels. Examples of DFB lasers are laser diodes that meet these requirements. By ensuring the reliability of the laser diodes, the reliability of the entire DWDM network can be guaranteed.

III. LITERATURE SURVEY

A large number of works are devoted to the study of the reliability characteristics of laser diodes. For example, in (1), the reliability of ILPN-134 semiconductor lasers was studied. The work [2] investigates the reliability of semiconductor GaAs lasers, and [3] - the reliability of underwater optical transmission systems. The influence of temperature and humidity on the lifetime of leaky laser diodes is discussed in [4, 5]. The study of the reliability of lasers with distributed feedback (DFB) is presented in [6], and laser transmitters with distributed Bragg reflection (DBR) with a wide tuning band of the radiation wavelength in [7].

An accelerated estimate of the service life of injection lasers and transmitting modules is considered in [8]. The most detailed issues of reliability of uncooled optical transmitters are considered in [9].

The work [10] is devoted to the reliability and degradation of semiconductor lasers and LEDs, and work [11] is devoted to optical devices based on group III – V semiconductors. The reasons for sudden failures of semiconductor

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lasers, the reliability of heterolasers, and an accelerated assessment of the service life of injection lasers are considered in [12, 13].

In this paper, the reliability of DFB laser diodes is assessed.

IV. METHODOLOGY

The long-term performance testing process for a laser diode is carried out to collect data on the lifetime of the LD under tightly controlled operating conditions and then to develop static models that can be used to predict the lifetime of the LD under the expected operating conditions. When examining the life of lasers, usually dozens of LDs are checked, and they are checked for at least 1000 hours.

Depending on the type and field of application, the process of long-term testing of laser diodes includes the study of periodic changes in their parameters, such as operating current, output optical power, threshold current, correct voltage in terms of aging. Accelerated aging of LDs can be achieved due to high temperature, high injection current, or optical action. However, a widespread method of forming accelerated aging under the influence of high temperatures.

The study of LD aging is carried out in one of three different operating modes [14]:

• Method of ACC (automatic current control). In this mode, the value of the current supplied to the LD is kept constant throughout the entire test;

Method of AOPA (Automatic Optical Power Adjustment Method). In this mode, the laser output optical power is kept constant by continuously adjusting the laser current. The output optical power of the LD is measured using an external photodetector or a built-in photodiode for laser control (if any). AOPA is relatively widely used in long-term LD performance tests. This is because this mode is similar to the specific operating mode (ie operating conditions) LD;

• Mode of periodic testing of samples. In this case, the LD is stored above 100 ° C and the temperature is periodically lowered to a low measurement level for measurement. In this type of test, the LD is in constant current mode during high temperature aging. During long testing, the interval between elections may vary throughout the testing process. This is done in order to reduce the amount of data collected. Samples for measurement should be separated every hour during the initial testing phase, samples can be separated every few days for measurement for several months after testing.

In this paper, the automatic current control method is used to assess the reliability of DFB laser diodes. As mentioned above, this method ensures that the pump current of the laser diode remains constant during the test. During the test, the output power of the laser diode shall decrease as a result of aging. The method of automatic control of a constant pump current for assessing the reliability of laser diodes is also important because it corresponds to real operating conditions.

V. EXPERIMENTAL RESULTS

In this work, 3 pieces of DFB laser diodes were obtained, from which samples of 3 pieces were formed. Accelerated tests were carried out in thermal chambers at a temperature of 80 ° C for 2000 h at a pump current Ip = 60 mA, corresponding to a pump and radiation current of 10 mW at a temperature of T = 60 ° C. Every 100 hours, the temperature in the chamber decreased to T = (60 ± 1) ◦C, and the values of the radiation power of each laser diode were recorded. After that, the temperature in the chamber was again set equal to 80 ° C, respectively, and the tests were continued at this pump current.

During testing, the output power of laser diodes at constant operating current is reduced. This leads to a decrease in the radiation power below the permissible limit value after a certain period of time. Deviation of the radiation power from the limit value leads to the fact that the optical signal does not reach the receiving side. This, in turn, causes interruptions in communication channels. The laser diode power reduction limit may differ from network to network. That is, the LD power suppression criterion depends on the optical budget in the used optical network.

In general, for today's research work, a 40% reduction in laser diode output power has been taken as a criterion for laser output power failure. As mentioned above, a total of 3 DFB type LDs were obtained for testing and are being tested at high temperatures in a thermal chamber. Measurement results were recorded every 100 hours. The result is 20 measurement results for each LD. Figure 1 below shows how the radiation power of each LD changes over time. This includes measurement results every 100 hours on the time axis.

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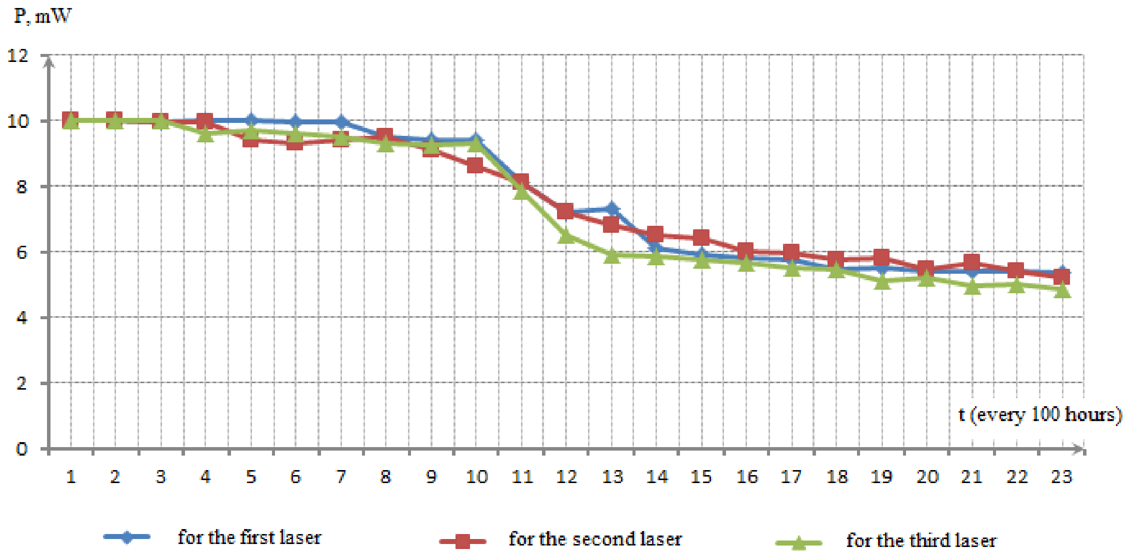

Fig. 1. Time dependences of the radiation power of laser diodes

As can be seen from the graph, each laser diode has different degradation mechanisms under the same exposure to high temperatures. Obtaining an exponential approximation of the graphs representing these degradation mechanisms, it is possible to derive a law of exponential decrease in the radiation power for each of them. I.e.

P1 = 11,286e-0,035t (1.1)
P2 = 11,696e-0,038t (1.2)
P3 = 11,593e-0,041t (1.3)

Based on all the obtained exponential laws (1.1), (1.2), (1.3), it is possible to derive a general law, and this is a general exponential mathematical law that can be used to predict the time of occurrence of a power drop in DFB laser diodes.i.e.

Pt = 11,525e-0,038t (1,4)

Using this formula, it will be possible to determine the radiation power of these laser diodes for an arbitrary moment in time. As noted above, a decrease in illumination by more than 40% is a criterion for rejecting LD in terms of radiation power. Therefore, using formula (1.4), it is possible to determine how long it takes for the initial radiation value to decrease from P0 = 10 mW to P1 = 6 mW, which is 40% of it. This makes it possible to predict the time of laser diode failure based on the radiation power.

VI. CONCLUSION AND FUTURE WORK

High-temperature testing of laser diodes in order to predict their service life is one of the most important processes in the development and manufacture of laser diodes. Although this testing process is relatively straightforward, the actual testing process is a complex process depending on the type of laser diodes, requirements such as high stability and long-term measurements. In particular, due to the storage of LDs at high temperatures, difficulties arise in measuring their operating parameters. It is also necessary to ensure that the measuring instruments are kept at a constant temperature while maintaining their stability.

Using the obtained experimental results, one can determine the mathematical law of the temperature dependence of the aging process of DFB lasers, and also make predictions about the subsequent activity of such LDs. This, in turn, improves the reliability of systems using DFB lasers.

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