Laser Diode Experiments for the Key Parameters Investigation

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Abstract**—**At the present time, there is a belief that the energy being absorbed in semiconductor elements of electronic devices is the key parameter that adequately characterizes the physical process of EMP influence on these elements [1]. But it should be noted that the distribution of absorbed energy in a semiconductor element depends on a variety of factors, including the time characteristics of the induced signals. As a result of the influence of these factors at the same value of the energy released, the consequences for the element may be different. So, it would be interesting to find a way of directly observing the processes occurring inside the semiconductor element, depending on the characteristics of the influencing electromagnetic pulses. It could be possible by measuring the light radiation spectrum for light-emitting semiconductor devices (LEDs or laser diodes). The results of experimental verification of this method are considered in the paper.

Keywords—electromagnetic pulse (EMP), pulse electric disturbance, laser diode.

I. THE EXPERIMENT IDEA

As an object under test, we chose a vertical-external-cavity surface-emitting-laser diode (VECSEL) that emits light with a wavelength of about 405 nm. The diode is powered by a current source. The normal operating current is I_0=30 mA. The laser diode is connected to a nanosecond pulse generator, which forms a rectangular pulse. These pulses simulate signals induced on the circuits of the device by EMP. The amplitude and duration of these pulses are chosen in such a way that the pulses have the same energy. The diode current was measured with a resistive shunt and a LeCroy WR64xi oscilloscope. The consequences of the current pulses influence on the laser diode operating mode were fixed in real time using a lattice spectrograph equipped with a recording system. This system is based on the Hamamatsu photoelectric modules and the multichannel photon counting module. The spectral resolution of the equipment used is 0.1 nm and time resolution is 0.4 ns. The optical fiber line was used to introduce light into the spectrograph.

II. THE EXPERIMENT RESULTS

Depending on the amplitude and duration of the current pulses, the following effects were observed: an increase in the concentration of nonequilibrium carriers in the region of the p-n junction and, as a consequence, an increase in the intensity of the laser radiation; intermode hopping; non-equilibrium heating of the VECSEL. As an example, Fig. 1 shows the wavelength dynamics of laser diode emission when a current pulse with 150 mA amplitude and 6 ns duration is applied to it. The effects mentioned above are shown.

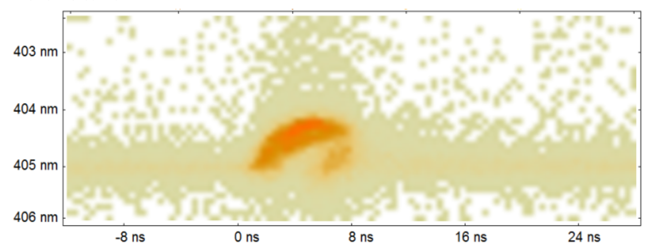

Fig. 1. Wavelength map for VECSEL when a current pulse is applied to it with 150 mA amplitude of and 6 ns duration.

The increase in the concentration of nonequilibrium carriers affects the intensity of the laser radiation and also leads to the wavelength change due to the increase in the Fermi energies for electrons and holes. For longer (more than 10 ns) current pulses, the diode heating caused by nonradiative recombination becomes noticeable and leads to a monotonic radiation wavelength shift.

SUMMARY

Thus, the influence of current pulses having the same energy, but of different amplitudes and duration, can lead to different physical effects in semiconductors and, as a consequence, to various disruptions in the functioning of electronic devices. This gives grounds for the research aimed at clarifying known key parameters determining the possibility of electronic device malfunction, and perhaps, on the use of new key parameters directly related to physical processes in semiconductors (for example carrier concentration and p-n junction temperature). It is assumed that the results obtained can be generalized to the case of other non-light-emitting semiconductor devices.

REFERENCES

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