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Effect of gamma irradiation on emission characteristics of laser heterostructures

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***Abstract*. Changes in the threshold current and slope efficiency are studied under conditions of gamma-ray irradiation by injection InGaAsP/InP lasers emitting at 1.3 μm (irradiation dose is ~10^{14} – 10^{17} photon cm^{-2}). We observed an improved performance at low values of the quantum flux density and degradation at doses greater than 10^{14} photon cm^{-2}.**

Keywords: *injection laser, threshold current, slope efficiency, irradiation dose, gamma rays.*

Expanding the use of a heterolasers requires new information about the behaviour of these types of lasers in conditions characteristic of specific applications. In particular, to employ such lasers on objects located in space or in optical systems with an autonomous power supply, such a characteristic condition is the presence of radioactivity.

To date, there were published a series of papers [1 – 5] devoted to the study of the effect of irradiation on the characteristics of heterostructures. However, unfortunately, the physical mechanisms of processes occurring in the gain medium of a laser in irradiation conditions are far from clear. The real situation corresponds to the stage of accumulation of experimental data. The focus of earlier research in this area was devoted to assessing the reliability (lifetime) of heterolasers in irradiation conditions.

The aim of this paper is to study the influence of gamma-ray irradiation dose on the threshold current and slope efficiency of InGaAsP/InP lasers. Heterolasers in question [6] operate in the spectral range of 1.3 μm and have a resonator of length L = 150 – 200 μm and an active region of width and thickness 2 – 7 μm and 0.15 – 0.2 μm, respectively. Although this type of laser currently does not have such high output characteristics as quantum-well lasers, they are quite acceptable, however, to solve the formulated problem, since the effect of irradiation on the active region is obviously not related to the quantum-dimensional effect. In lasers with a bulk active region, degradation is far more than an order of magnitude higher than in lasers with a quantum-well active region.

In the experiment we used 27 heterolasers with an average threshold current of 70 mA at 25 °C. Prior to irradiation, to assess their performance we conducted short-term tests of lasers (10 h) at 70 °C and a constant output power of 0.5 mW. The light – current characteristics of the samples were measured automatically.

After selection the samples were irradiated with gamma-rays from a ^{60}Co source (gamma-ray energy is E'_{γ} = 1127 keV, E''_{γ} = 1333 keV) at different doses ranging from 10^{14} to 10^{17} photon cm^{-2}). Then, we measured again the light – current characteristics of lasers to determine the change in threshold current I and slope efficiency η_d. Figure 1 shows the change in the threshold current of different samples vs. the radiation dose. As can be seen from the figure, the threshold current of lasers at doses 10^{14} – 10^{15} photon cm^{-2} decreases, and at doses greater than 10^{15} photon cm^{-2} the threshold current begins to increase linearly. The current in this region can be represented as a function

$$I = I_0(1 + A\Phi),$$

where I_0 is the initial value of the threshold current; Φ is the irradiation dose. In our experiment, the mean value of A is ~10^{-18} cm^2.

Figure 2 shows the change in the slope effectiveness vs. the irradiation dose. It is seen that at doses 10^{14} photon cm^{-2} the value of η_d increases, and then decreases with increasing radiation dose.

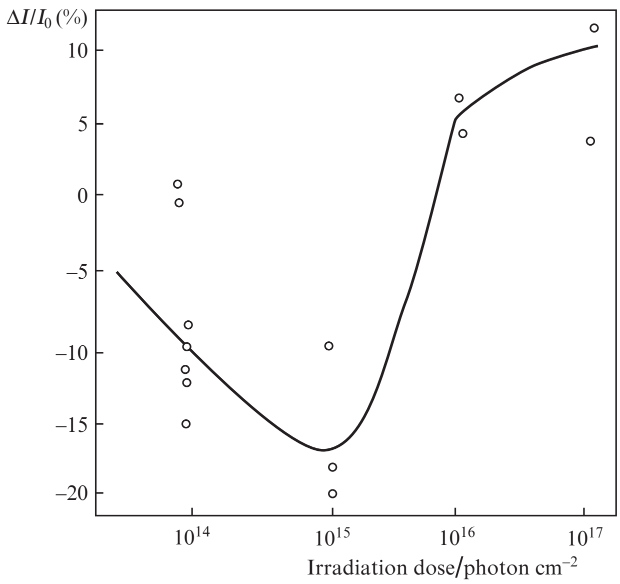

Figure 1. Relative change in the threshold current of lasers vs. irradiation dose for different samples.

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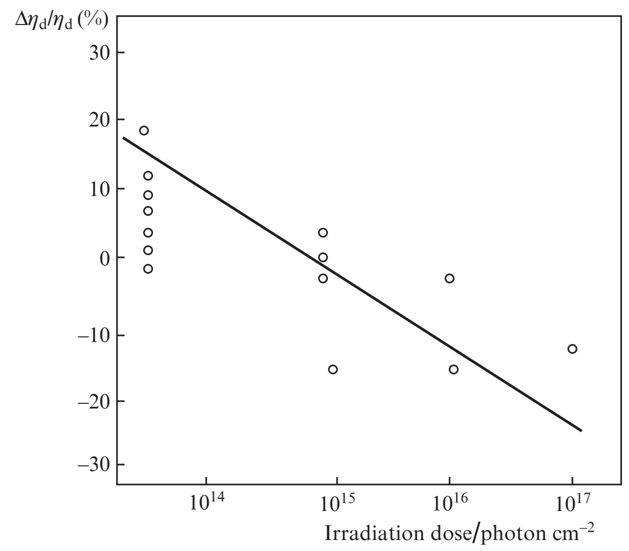

Figure 2. Relative change in the slope efficiency of lasers vs. irradiation dose for different samples.

The change in the threshold current and slope efficiency of lasers as a function of the radiation dose depends on the initial value of the slope efficiency. Figures 3 and 4 show the behaviour of these dependences at the same dose (10^{14} photon cm^{-2}).

In general, the dependence of I and η_d on the irradiation dose can be interpreted as follows. At the irradiation dose of 10^{14} photon cm^{-2}, we observe a change both in the threshold current and slope efficiency. Irradiation affects the efficiency and internal loss α (η_d increases, and α decreases). At the irradiation dose of 10^{15} photon cm^{-2}, the threshold current decreases (η_d does not change). The flux of gamma rays produces point defects and clusters, which stop rapidly moving impurity ions. A decrease in the threshold current is due to the quenching of microplasmas and annihilation of defects that existed prior to irradiation (reduction of loss α). At the irradiation dose of ~10^{16} photon cm^{-2}, we observe an increase in the threshold current and a decrease in the slope efficiency because new radiation nonradiative centres are formed.

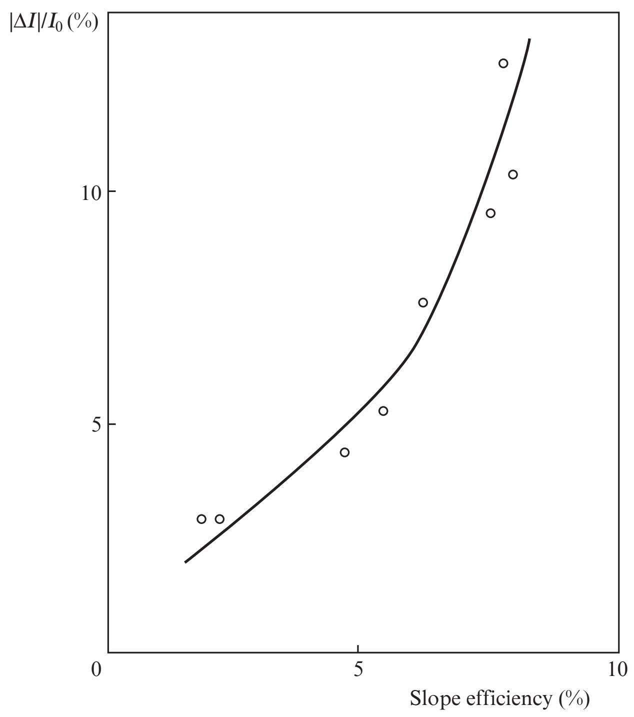

Figure 3. Relative change in the threshold current of lasers vs. initial value of the slope efficiency of the samples at the irradiation dose of ~10^{14} photon cm^{-2}.

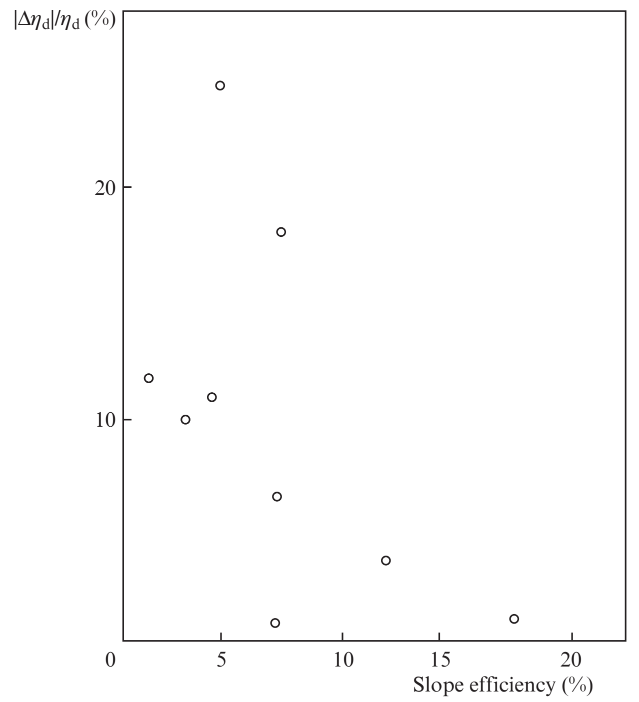

Figure 4. Relative change in the slope efficiency vs. initial value η_d of samples at the irradiation dose of ~10^{14} photon cm^{-2}.

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