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A TECHNIQUE FOR INCREASING THE THERMAL STABILITY OF THE PULSE RADIATION POWER OF INJECTION LASERS

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We show that stabilization of the delay of generation in AlGaAs and InGaAsP heterolasers increases the thermal stability of their pulse radiation power. This compensates for the temperature dependence of the theshold current of the laser, and the thermal stability of the laser radiation power is determined in the main by the temperature dependence of the quantum efficiency and lifetime of nonequilibrium charge carriers.

The accuracy of measuring distances by light range finders, the time of reliable data storage in optoelectronic dynamic memories, and other accuracy indices of laser measuring systems that are based on injection lasers (IL) depend greatly on their radiation power stability. Despite great successes in the development of multipurpose high-power injection lasers with a long service life the task of increasing their radiation power stability in the pulse mode remains urgent [1].

The strong temperature dependence of the generation threshold of injection lasers [2] is a result of a great variety of factors [2] and is responsible for the temperature dependence of generation power. Therefore, the problem of developing methods for stabilizing the radiation power of injection lasers that are insensitive to the mechanism of the destabilizing effect exerted on them is of extreme importance. The occurrence of radiation generation in an injection laser is of a threshold character, while its delay t_d relative to a pumping pulse is determined by the excess of the injection current I over the threshold value I_{thr}. It is of interest to investigate the temperature dependence of IL pulse radiation power if the stimulated radiation delay is held at a given value. The implementation of such a regime of IL generation is easily realized on the basis of the recently developed principle of priority time discrimination [3, 4], with the accuracy of time stabilization attaining 20–30 psec [5].

To analyze the temperature dependence of the IL generation power in the radiation stabilized delay mode we write the power $P_g(\Theta)$ and the stimulated radiation delay $t_d(\Theta)$ for a current pulse of step shape in the form

$$P_g(\Theta) = \frac{h\nu}{e}\eta_{dif}(\Theta)\,[I - I_{thr}^{st}(\Theta) + I_0]\,, \tag{1}$$

$$t_d(\Theta) = \tau(\Theta)\ln\,[I/(I - I_{thr}^{st}(\Theta) + I_0)]\,. \tag{2}$$

At $t_d = \text{const}$ Eq. (2) yields

$$I_0 = I\,[\exp(-t_d/\tau(\Theta)) - 1] + I_{thr}(\Theta)\,. \tag{3}$$

Substituting Eq. (3) into Eq. (1), we obtain

$$P_g^{st}(\Theta) = \frac{h\nu}{e}\eta_{dif}(\Theta)\,I\exp\,[-t_d/\tau(\Theta)]\,. \tag{4}$$

From Eq. (4) it follows that, with the regime t_d = const being maintained by adjusting the dc bias current I_0, compensation of the temperature dependence of the IL generation threshold occurs, and the function $P_g^{st}(\Theta)$ is

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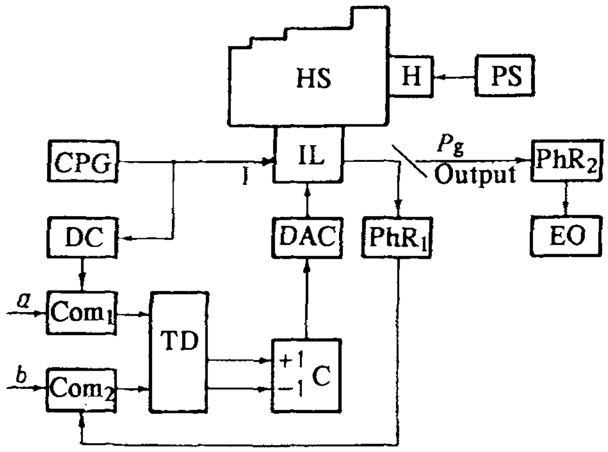

Fig. 1. Functional diagram of experimental setup for investigating the temperature dependence of IL radiation power.

determined by the functions $\eta_{dif}(\Theta)$ and $\tau(\Theta)$. In the temperature range Θ = 250– 330 K the function $\tau(\Theta)$ can be approximated by the expression [2]

$$\tau(\Theta) = \tau_r = k_\tau (\Theta - \Theta_r) , \tag{5}$$

where for an AlGaAs IL $k_\tau \approx 3.6 \cdot 10^2$ nsec/K [2, 3].

Taking into account the fact that, in contrast to $I_{thr}(\Theta)$, the functions $\tau(\Theta)$ and $\eta_{dif}(\Theta)$ in the temperature range 250–330 K for an AlGaAs IL are weak functions of temperature [3] and using Eqs. (1), (4), and (5) we obtain

$$\left| \frac{dP_g}{d\Theta} \right| > \left| \frac{dP_g^{st}}{d\Theta} \right| . \tag{6}$$

Condition (6) shows that stabilization of the generation delay in the laser increases the thermal stability of IL pulse radiation power.

In order to investigate the efficiency of the method suggested, we used the experimental setup whose functional diagram is presented in Fig. 1. The setup includes the injection laser investigated, which is excited by a current-pulse generator (CPG). Dc bias I_0 was supplied to the injection laser from a digital-analog converter (DAC). The output signals from the current-pulse generator (through a delay circuit (DC)) and from a photoreceiver (PhR_1), which detects a portion of the radiation from the output of the injection laser investigated, entered comparators Com_1 and Com_2 with response thresholds a and b. The times at which the pulse signals appeared at the outlets of the comparators were compared in a time discriminator (TD), and the TD output pulses were calculated by a counter C. The output code of the counter was supplied to the data inputs of the digital-analog converter.

The injection laser investigated was installed on a massive heat sink HS. The heat sink (and simultaneously the injection laser investigated) was heated by a heater (H) powered by a regulated power supply (PS).

Assuming that pulses at the inputs of comparators Com_1 and Com_2 have a linear front, the difference between the times Δt of the arrival of the pulses to the inlets of time discriminators can be written in the form

$$\Delta t = \tau_2 b/U_2 + t_d(\Theta, I_0) - \Delta t_d - \tau_1 a/U_1 . \tag{7}$$

If $|\Delta t| > \Delta\tau$ is determined according to Eq. (7), then for each pulse supplied from the current pulse generator, an automatic adjustment of the IL dc bias by δI_0 is made in the system. This process is repeated until the condition $|\tau_2 b/U_2 + t_d(\Theta, I_0) - \Delta t_d - \tau_1 a/U_1| \leq \Delta\tau$ is satisfied. After this condition is attained at the exit from the photoreceiver PhR_2, the pulse signal amplitude, which is proportional to the IL radiation power, is monitored by an electronic oscillograph (EO).

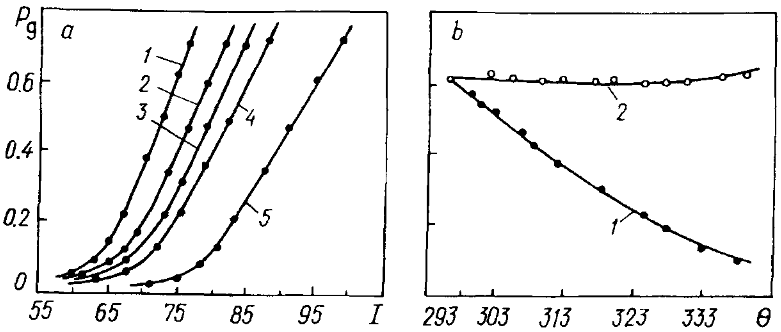

Fig. 2. Dependence of the generation power P_g of an InGnAsP IL in relative units on the injection current I at temperatures 293, 300, 308, 314, and 328 K (a) curves 1-5, respectively) and on the temperature Θ (b). I, mA; Θ, K.

We investigated the temperature dependence of the generation power of an InGaAsP IL with radiation wavelength $\lambda = 1.3\ \mu m$. Typical watt-ampere characteristics of these lasers at different temperatures are shown in Fig. 2a. It is seen that for this type of laser the quantum efficiency decreases noticeably (the slope of the watt-ampere characteristic decreases) with an increase in temperature. The function $P_g(\Theta)$ of an InGaAsP IL at $I = 75$ mA, $I_0 = 0$ without controlling the delay in the IL is shown in Fig. 2b (curve 1). The temperature coefficient of power in the range 250–330 K is equal to $\Delta P_\Theta \cong -0.5\%/K$. If the delay in generation in an injection laser is held constant by adjusting I_0, then the generation power is stabilized in the indicated temperature range (see Fig. 2b, curve 2).

Earlier we investigated the temperature dependence of the generation power of an AlGaAs IL in the regime of stabilized delay [6]. We found that in this regime $\Delta P_\Theta \cong +0.25\%/K$ for the AlGaAs IL (an increase in power with a rise in temperature). No recompensation of pumping with an increase in temperature occurs in an InGaAsP IL. This seems to be due to a stronger dependence $\eta_{dif}(\Theta)$.

Thus, for an AlGaAs or InGaAsP IL, stabilization of the delay of generation in the laser increases the thermal stability of the pulse power of radiation. It should be noted that this method simultaneously solves another important problem, i.e., it stabilizes the time position of the IL radiation pulse with respect to the injection current pulse, which is especially important for creating optoelectronic recirculation systems. The method developed is sufficiently simple to implement in hardware and can find wide application in measuring systems based on injection lasers.

NOTATION

I_{thr}^{st}, threshold current of laser for a stationary generation regime; t_d, delay in stimulated radiation generation in laser; P_g, power of laser generation; h, Planck constant; ν, radiation frequency: e, electron charge; Θ, absolute temperature; Θ_r, room temperature; η_{dif}, external differential quantum yield of laser; I, amplitude of the laser pumping current pulse; I_0, dc bias current of laser; τ, lifetime of nonequilibrium current carriers in laser; P_g^{st}, laser generation power in the mode of stabilized delay of radiation; k_τ, parameter for approximation of temperature dependence τ; τ_r, lifetime of nonequilibrium charge carriers in laser at room temperature; a and b, thresholds of operation of comparators Com_1 and Com_2; Δt, difference between the times at which the fronts of pulses arrive to the inputs of the time discriminator; τ_1 and τ_2, rise times of pulses at inputs to comparators Com_1 and Com_2; Δt_d, time of propagation of pulse signal in the delay circuit; U_1 and U_2, amplitudes of the voltage pulses at the inputs of the comparators Com_1 and Com_2; $\Delta\tau$, time resolution of discriminator; λ, laser radiation wavelength; ΔP_Θ, temperature coefficient of laser power.

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