INVESTIGATION OF THE RADIATION PULSATIONS OF A CW GaAs INJECTION LASER

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An investigation of the dynamics of radiation of semiconductor GaAs lasers operating in the pulsed generation regime has shown that the radiation of the diodes consist of a sequence of short light pulses with a period and duration $\sim 10^{-9} - 10^{-11}$ sec [1 - 4]. The presence of intensity pulsations in the CW emission of laser diodes operating [5] proves that the emission spikes are due to nonlinear absorption of the radiation in the active region of the diode, and not to the nonstationary nature of the pulse of the injected current.

We investigated the dynamics of the emission of a number of diodes with threshold density 600 - 800 A/cm^2 when cooled with liquid nitrogen. The time structure of the radiation was investigated with the aid of an electron-optical converter (EOC) with a time sweep [6]. The time resolution of the instrument was $\sim 3 \times 10^{-11}$ sec. The magnified image of the diode was focused on the EOC cathode, so that it was possible to view on the screen of the instrument separate regions of the p-n junction, with dimensions on the order of 40 μ. Observation of the near field of the diode radiation shows that the laser emission comes from individual regions.

The most characteristic picture of the development of generation in the diodes operating in the continuous regime is the absence of intensity pulsations in the radiation of the channels having the lowest generation threshold, even when the threshold is appreciably exceeded. At the same time, spikes are observed in the radiation of channels whose generation threshold is much higher (1.5 - 2 times) than the diode generation threshold. Thus, the presence of radiation losses in the channels leads to a noticeable increase of the generation threshold in the channels and to the establishment of a pulsating radiation regime. The spikes radiated by the channels with high threshold are essentially regular and similar to the spikes radiated by double diodes under inhomogeneous excitation. Figure 1 shows an oscillogram of the diode radiation in the continuous regime, photographed from the EOC screen. The injection current exceeds the threshold by a factor 1.9.

It should be noted that at times radiation pulsations are observed already at a small excess above threshold (5 - 10%). Such spikes are irregular, and their average period and duration decrease with increasing injection current. The dependence of the average period of these pulsations on the current is similar to the dependence determined in [4] for single diodes operating in the pulsed regime.

Spectral investigations of the radiation of laser diodes operating in the continuous regime were made with the aid of a spectrometer with resolution ~ 0.5 Å. At a slight excess

Fig. 1. Oscillogram of continuous diode emission, photographed from EOC screen. Injection current 1.9 times threshold. Sweep duration 10 nsec.

Fig. 2. Oscillograms illustrating different diode operating regimes: a - stationary diode emission, $I/I_{thr} = 1.6$; b - ultrashort spike regime, $I/I_{thr} = 2$; c - regular spike regime, $I/I_{thr} = 2.2$. Sweep duration 10 nsec.

above threshold, with the diode radiation stationary in time, the half-width of the emission spectrum was 2 - 5 Å, and no discrete lines corresponding to the laser resonator modes were observed in the spectrum. The regular-pulsation radiation regime corresponds to the onset of generation from a new laser channel, emitting a spectral line shifted 10 - 15 Å towards the shorter wavelengths compared with the earlier spectrum. The half-width of the emission spectrum of the new channel is also several Angstroms. The emission of a shorter-wavelength spectrum by the channels operating in the regular-pulsation generation regime is evidence in favor of the assumption that such channels have appreciable absorbing regions.

Simultaneous generation of spikes with a slight time delay from neighboring closely-lying channels can apparently lead to the appearance on the oscillograms of the ultrashort spikes, with period 0.05 - 0.1 nsec, which were observed earlier in [4]. The ultrashort-spike radiation regime sometimes precedes the appearance of regular pulsations. Figure 2 shows diode-radiation oscillograms at different injection currents, illustrating the occurrence of ultrashort pulsations. Oscillogram a shows the stationary radiation of the diode when the threshold is exceeded by 1.6 times. Oscillogram b corresponds to the generation threshold exceeded 100%. Further increase of the pump current leads, as the result of the large interaction between the neighboring channels, to synchronization of the radiation of the channels [7] and to establishment of a regime of simultaneous generation of spikes whose period is several times larger than the period of the ultrashort spikes (oscillograms c, ratio of injection current to the threshold 2.2). The broadened emission spectrum of the investigated diodes offers evidence that the ultrashort spikes can be generated by neighboring interacting channels located in one radiating region and having overlapping spectral lines.

The time structure and the spectral composition of the radiation of the investigated diodes differs little when operating in the continuous generation regime from the characteristics of radiation in the pulse regime. In both regimes, the regular pulsations appear when generation is established in the radiation channel with high generation threshold.

Thus, investigations of the dynamics of radiation of diodes operating both in the continuous and in the pulsed regimes show that the main mechanism determining the appearance of pulsations in nonlinear absorption of radiation by sections in the active region of the diodes, resulting from the uneven distribution of the injection current or from optical inhomogeneity of the p-n junction itself.

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