SYNCHRONIZATION OF GALLIUM ARSENIDE LASER LIGHT PULSES

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Results are presented of an investigation of the radiation from a laser operating in the spike mode when a high-frequency signal is applied simultaneously with the injection-current pulse. The amplitude of the high-frequency current was several per cent of the injection current. Regimes of diode radiation modulation and regimes of capture of the laser spikes by an external force are investigated. The frequency of the synchronized light spikes is exactly the same as that of the high-frequency generator, and the duration of the spikes is determined by the level of the injection current. The region of spike capture is determined and its boundaries are shown to shift towards higher frequencies with increasing pumping-current amplitude.

INVESTIGATIONS of the emission characteristics of a semiconductor laser using gallium arsenide have shown that at a definite amplitude of the injection current through the p–n junction, the laser operates in the spike mode, and the period and duration of the light pulse have an irregular character during the current injection pulse.[1, 2] With increasing injection current, the distances between the spikes and the durations of the individual spikes decrease.

To obtain distinct and regular spikes (see [2]), a diode was used with uneven injection-current density over the area of the p–n junction. From theoretical and experimental investigations of the operation of such a "slotted" diode[3] it follows that the spike mode is realized in a laser only when the density of the current injected in one of the parts of the diode is several times larger than the density of the current in the other part, so that one part of the diode operates like an amplifier, and the other plays the role of an easily saturated nonlinear filter (absorber).

In this paper we present the experimental results of an investigation of the possibility of synchronizing the intrinsic irregular spikes generated by an ordinary "unslotted" solid-state laser, with the aid of a current from a high-frequency standard signal generator. To this end we applied to the laser, simultaneously with the injection-current pulse, a signal from the G4-5 sinusoidal-oscillation high-frequency generator. The amplitude of the high-frequency current was several per cent of the amplitude of the injection current. During the time of the operation, the diode was cooled with liquid nitrogen. The laser emission was registered with the aid of an electro-optical converter (EOC) with sweep. The time resolution of the instrument was $\approx 3 \times 10^{-11}$ sec.

When a high-frequency current was applied to a diode operating close to or at the threshold, ordinary high-frequency modulation of the laser emission was observed. An analysis of the emission in this case shows that it has a purely sinusoidal variation with a frequency equal to the frequency of the master generator in the entire range of its variation. It should be noted that in the absence of the high-frequency current, the diode emission has no spikes at this injection level.

When a current pulse exceeding the threshold by 10–15% was applied to the diode, the latter began to operate in the irregular spike mode. By applying to it a signal from the high-frequency generator, whose period is shorter than the distance between the individual spikes, it was possible to lock the laser spikes by an external force.

When the generator frequency was varied, the spike frequency was varied, remaining exactly equal to the frequency of the master generator. The spike synchronization was observed in the frequency range from 400 to 1000 MHz. The capture region depends on the amplitude of the injection current, shifts towards larger frequencies when the injection current is increased, and amounts to $\approx$ 200 MHz.

Figure 1 shows spike oscillograms photographed from the EOC screen. The upper oscillogram (Fig. 1a) corresponds to the diode emission mode with the high-frequency generator disconnected. The lower oscillogram (Fig. 1b) corresponds to the same diode operating mode, when the signal from the high-frequency generator is simultaneously applied to it. As seen from the figures, in the former case the laser emission has a clearly pronounced irregular spike character, and the second case the spikes have a pronounced regular

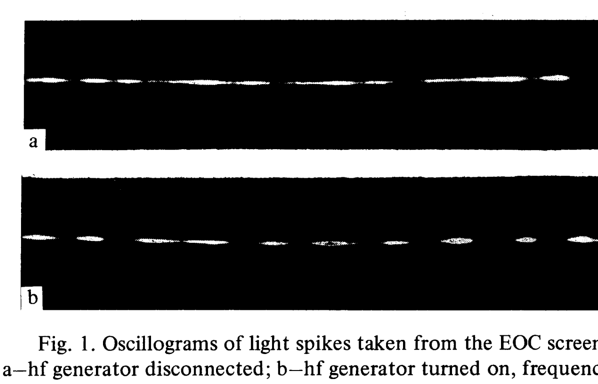

Fig. 1. Oscillograms of light spikes taken from the EOC screen: a—hf generator disconnected; b—hf generator turned on, frequency f = 680 MHz. Injection current $I = 1.2I_{thr}$ in both cases. Oscillogram sweep duration $\approx$ 14 nsec.

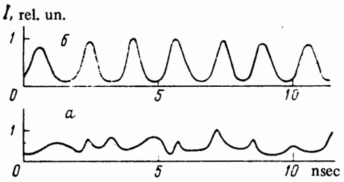

Fig. 2. Results of photometry of the oscillogram of the solid-state laser emission: a—hf generator off; b—solid-state laser emission in the synchronization mode.

character with a repetition frequency equal to the frequency of the high-frequency generator. The peak power of the synchronized pulses depended on the injection current and amounted to a fraction of a watt.

Figure 2 shows the results of photometry of the diode-emission oscillogram. Figure a corresponds here to the laser operation with the high-frequency generator disconnected, and Fig. b to operation with the high-frequency generator.

The photometry of the emission oscillograms shows that the off-duty cycle of the spikes in the synchronization mode amounts to 3 – 5. The duration of the light spikes, measured at half-width of the intensity variation, is practically independent of the frequency of the high-frequency generator within the limits of the band of locking by the external force. When the injection current changes, the duration of the synchronized spikes changes but their repetition frequency remains equal to the frequency of the master generator.

The foregoing experimental data on the generation and synchronization of solid-state laser spikes pertain to diodes of sufficiently large size (length ~ 1.5 mm). It should be noted that with decreasing linear dimensions of the diode, the frequency of the intrinsic spikes increases, and their duration decreases. Thus, for example, in diodes ~ 100 μ long one observes random light pulses of duration ~ 10^{-11} sec at an average repetition frequency 10^{10} Hz. Thus, by varying the linear dimensions of the diode and by using the mode of synchronization of the random spikes in the laser by means of a high-frequency generator, it is possible to ensure a smooth regulation of the frequency and of the duration of the light pulses in a wide interval of the nanosecond band from 10^{-9} to 10^{-11} sec. Consequently, such a device can serve as a generator for adjustable ultrashort light pulses.

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