HYSTERESIS OF RADIATION POWER OF GALLIUM-ARSENIDE INJECTION LASERS

V. N. Morozov, V. V. Nikitin, and V. D. Samoilov
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 5 August 1968
ZhETF Pis. Red. 8, No. 8, 410 - 413 (20 October 1968)

In [1-2] we investigated semiconductor laser using gallium arsenide with an injection-current density that was not uniform over the p-n junction area. Such a semiconductor laser constitutes a set of two electrically insulated diodes in a common resonator [3]. If the excitation inhomogeneity is appreciable and the current in one part is much smaller than the current in the other part, then the amplitude of the coherent radiation assumes its final value jumpwise, i. e., a hard generation regime sets in.

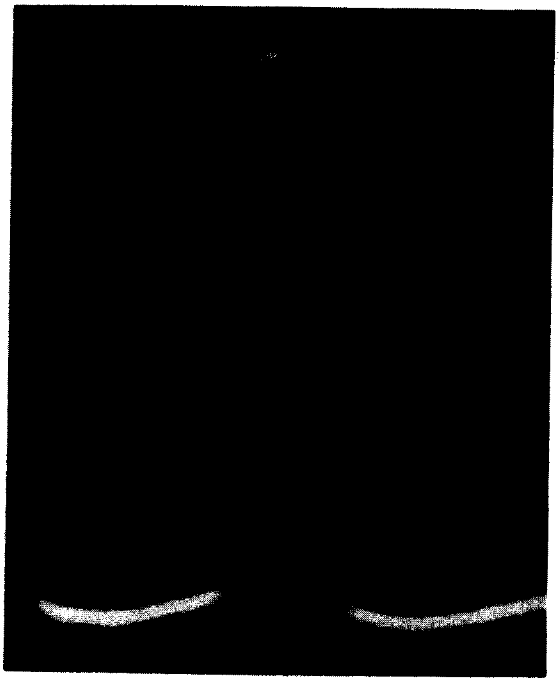

Fig. 1

We report in this paper an experimental observation of hysteresis in the power of coherent radiation of GaAs lasers operating in the hard regime [2]. The hysteresis is manifest in the fact that the generation starts and stops at different injection-current levels.

The power hysteresis of a GaAs injection laser was investigated in the following manner. Using the known current-power characteristic of the diode, the currents I_1 and I_2 in the two parts were adjusted to make the system operate in the hard regime close to the self-excitation threshold. An additional sinusoidal current was fed to the absorbing part, with an amplitude such that the total level of the injection current satisfied the threshold conditions in the positive half-wave of the sinusoid. The lower part of the oscillogram of Fig. 1 shows the amplitude-modulated spontaneous emission. Coherent emission appears jumpwise at a definite value of the current in the positive half-wave of the sinusoid. The magnitude of the jump depends on the degree of inhomogeneity of the excitation. As seen from Fig. 1, the drop of the generation from the stable coherent-emission state to the spontaneous-emission regime occurs in the negative half-wave of the modulating curent, when the total injection current is lower than the value required for the onset of generation. By varying the amplitude of the sinusoid and the reference injection currents, it was possible to measure the range of currents in which the hysteresis loop exists. This range depends on the ratio of the injection currents in the different parts of the diode, and amounts on the average to several dozen milliamperes, i.e., to one per cent or less of the total injection current.

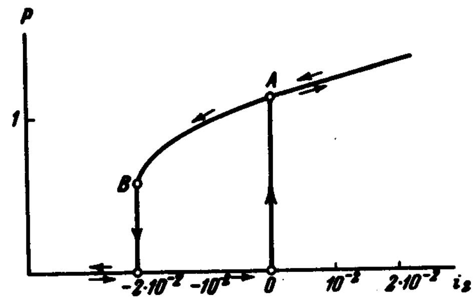

Fig. 2. Theoretical plot of laser radiation power vs. injection current in the absorbing part (hysteresis loop) in the hard generation region.

On the basis of [2], we plotted in Fig. 2 the theoretical dependence of the radiation current on the injection current in the absorbing part, with the current I_1 in the amplifying part kept constant. The axes are the coherent radiation power P in relative units and the quantity $i_s = (I_2 - I_{2thr})/I_{thr}$, where I_2 - injection current in the absorbing part and I_{2thr} - threshold value of this current, i.e., the value at which the gain equals the loss when there are no photons in the resonator; I_{thr} - threshold injection current under homogeneous excitation. Under the conditions of the experiment shown in Fig. 2 we have $I_1 = 2.1I_{thr}$ and $I_2 = 0.12I_{thr}$. When the injection current is increased from a certain value to I_{2thr}, the power of the coherent radiation becomes equal to zero, since the gain is lower than the loss in weak fields. In the hard regime, the gain as a function of the number of photons has a maximum, and the gain equals the loss at two values of the emission intensity. At the point $I_2 = I_{2thr}$ the power jumps to a stable state a, since the initial state P = 0 is unstable. When the current I_2 decreases, the power decreases until the stable and unstable points merge into one. In this case, the plot of the total gain against the photon number will be tangent to the line corresponding to the loss level. With further decrease of the current, the only possible state of the system is P = 0, i.e., the generation stops abruptly. Under the conditions of the experiment shown in Fig. 2, the range of variation of the injection current, in which the hysteresis exists, is 2% of the threshold current under homogeneous excitation.

The hard regime of the onset of generation and the hysteresis of the power of the coherent emission are observed in solid-state and in gas lasers [4, 5]. It is necessary for this purpose to introduce into the resonator another medium, such as a saturable solution or a nonlinearly absorbing cell with specially chosen gas parameters. An essential advantage of GaAs semiconductor lasers with inhomogeneous injection density is that one can use as the nonlinear absorbing element one of the parts of the laser, to which a sufficiently small injection current is fed. This makes it possible to study the dynamics of laser generation in a wide range of variation of the degree of nonlinearity of the absorption.

[1] Yu. P. Zakharov, V. V. Nikitin, and V. D. Samoilov, Fiz. Tekh. Poluprov. 2 (1968) (in press) [Sov. Phys.-Semicond. 2, in press].

[2] V. N. Morozov, V. V. Nikitin, and V. D. Samoilov, Zh. Eksp. Teor. Fiz. 55, 1619 (1968) [Sov. Phys.-JETP 28, (1969)].

[3] G. I. Lasher, Sol. St. Elect. 7, 707 (1964).

[4] B. L. Borovich, V. S. Zuev, and V. A. Shcheglov, Zh. Eksp. Teor. Fiz. 49, 1031 (1965) [Sov. Phys.-JETP 22, 717 (1966)].

[5] A. P. Kazantsev, S. R. Rautian, and G. I. Surdutovich, ibid. 54, 1409 (1968) [27,(1968)]