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Continuous Operation of an Injection Laser on GaAs When Cooled by a Stream of Gaseous Helium

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The creation of an injection laser with continuous radiation presents well-known difficulties. The principal obstacle to achieving continuous operation is temperature limitations (1). Indeed, as the temperature of the sample increases, the probability of radiative recombination drops sharply and the spectrum of spontaneous emission broadens, which makes it difficult to obtain an inverted distribution of carriers in the semiconductor. All this leads to an increase in the threshold current and, consequently, to additional heating of the sample.

The amount of heat released in the sample during continuous operation per unit time may be described by the expression:

$$Q = I^2 R + I U_k [1 - \eta(1 - K)], \quad (1)$$

where I is the current flowing through the diode; R is the resistance of the sample when the barrier at the p-n junction is removed; U_k is the voltage drop across the p-n junction; η is the internal quantum yield; K is a coefficient characterizing the thermal losses of spontaneous and stimulated radiation in the sample. Only in the ideal case, when $K = 0$ and $\eta = 1$, does equation (1) take the form $Q = I^2 R$, i.e., the heating of the sample is due only to the release of Joule heat as current passes through the diode.

Thus, in order to achieve high efficiency in converting electrical energy into radiation and to obtain continuous generation, cooling of the semiconductor and good removal of heat from its active region are necessary.

At present, several reports are known on obtaining continuous generation in an injection laser on GaAs. In the first report (2), the diode was immersed in liquid helium in the superfluid state. As the temperature increased when helium passed from the superfluid to the ordinary state, continuous generation ceased. In another work (3), to obtain continuous operation at a temperature of 20.5°K, specially selected materials were used which, at this temperature, along with GaAs, possessed optimal thermal characteristics.

Fig. 1. Layout of the experimental setup for observing continuous emission from a GaAs laser.

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To obtain continuous generation we used a GaAs diode mounted on a standard triode stem. The *p*–*n* junction was formed by diffusion of Zn from the vapor phase into a wafer oriented along the (111) plane. The starting material was gallium arsenide doped with Te, obtained by the Bridgman method. Diffusion was carried out in an evacuated and sealed quartz ampoule under excess As vapor pressure. The resonator faces were obtained by cleavage. The area of the *p*–*n* junction was 0.34×0.4 mm^2. To create ohmic contacts, an indium-based alloy was used: on the *p*-side with an addition of Zn, and on the *n*-side with an addition of Sn.

The layout of the experimental setup for obtaining continuous operation is shown in Fig. 1. One of the principal elements of the experimental setup is a gas cryostat, consisting of a double-walled silvered glass tube, the space between whose walls has been evacuated. One end of the tube, together with the heater, is lowered into a Dewar vessel with liquid helium. At its other end, in front of the window, a diode is placed in immediate proximity to the nozzle. The degree of cooling can be regulated over wide limits by the rate of gas flow through the nozzle. With this method of cooling, the thermal regime of the diode is determined mainly by the thermal characteristics of gaseous helium and gallium arsenide. The temperature was measured with a copper–constantan thermocouple attached in immediate proximity to the sample.

The generation threshold was observed with a viewing tube with an electron-optical converter, from the appearance of interference rings on a Fabry–Perot etalon. The etalon thickness was 0.3 mm.

Fig. 1. Layout of the experimental setup for observing continuous emission from a GaAs laser. 1 –GaAs diode; 2 –gas cryostat; 3 –liquid helium; 4 –heater; 5 –exit windows; 6 –lens; 7 –Fabry–Perot interferometer; 8 –storage-battery bank; 9 –viewing tube with an electron-optical converter.

When immersed in liquid nitrogen in pulsed operation, with a pulse duration of 7 μsec and a pulse repetition frequency of 50 Hz, the threshold current density was 1300 A/cm^2; in the same regime in a stream of gaseous helium at a temperature of 30° K, it was 230 A/cm^2. Thus, in pulsed operation, as the temperature was lowered the threshold decreased almost by a factor of 6, which is very close to the data of Ref. (4). In continuous operation the laser operated in the temperature interval 25–35° K. At a temperature of 30° K the threshold current density was 360 A/cm^2, which is connected with heating of the diode.

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Note: Figure translations are in progress. See original paper for figures.