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High-power 2.5-W cw AlGaAs/GaAs laser diodes

A V Aluev, A M Morozyuk, M Sh Kobyakova, A A Chel'nyi

Abstract. **2.5-W cw laser diodes with a 100-μm wide strip contact emitting at a wavelength of 850 nm are manufactured and studied. The laser heterostructure with a heavily-doped *P* emitter was prepared by the metal-organic chemical-vapour deposition (MOCVD) technique in the AlGaAs/GaAs system. For a cavity of length 800 μm, the external differential quantum efficiency was 84 % (1.2 W A^{-1}), and the characteristic threshold current temperature was 230 K. The predicted service life of the laser is more than 5×10^3 h.**

Keywords: *high-power laser diode, mesastripe structure.*

1. Introduction

High-power semiconductor lasers are widely used for pumping solid-state lasers, in medicine, and in material machining. To obtain high radiation powers, an efficient emitter with a low threshold current density and a high differential quantum efficiency is required. It was shown in papers [1 – 4] that to increase the limiting radiation power and the service life of the emitters, the radiation power density at the cavity output should be reduced. This is usually achieved by reducing the optical confinement in the laser waveguide, which leads to a decrease in the beam divergence in a plane perpendicular to the plane of the heterostructure. However, a decrease in the optical confinement results in an increase in the threshold current density, while a decrease in the height of the heterobarriers increases the leakage current from the active region and decreases the external quantum efficiency.

In this paper, we report the development of a 2.5-W cw laser diode with a stripe contact of width 100 μm. The laser emits at 850 nm with a 40° beam divergence in the far-field zone. The high output power was achieved due to a strong doping of the *P* emitter.

2. Experimental

The laser heterostructure was fabricated by the MOCVD technique in a quartz split-flow reactor working under a reduced pressure. The graphite substrate holder was heated to 700 °C by an RF generator. The graphite substrate holder was rotated at the rate of 30 rpm to improve the homogeneity of the composition and to increase the thickness of the layers being deposited. Hydrogen was used as the carrier gas. Triethyl gallium, trimethyl aluminium and diethyl zinc were used as sources of Ga, Al and Zn, respectively. The metalloorganic compounds were thermally stabilised at a temperature of +17 °C. Concentrated arsine was used as the source of arsenic. The GaAs and AlGaAs films were doped with silicon from a 1 % SiH_4/Ar mixture to produce *n*-type layers.

The epitaxial setup was equipped with a bypass/reactor pressure balancing system, as well as with pressure regulators in all MOC lines, which prevented the development of transient hydraulic phenomena in the gaseous system and in the reactor upon a mutual switching of gas flows.

Gallium arsenide wafers grown by horizontal unidirectional crystallisation and having a carrier concentration $n = 2 \times 10^{18}$ cm^{-3} were used as substrates.

The double quantum-well separate confinement heterostructure was formed by the following sequence of layers: a GaAs : Si buffer layer with $n = 2 \times 10^{18}$ cm^{-3}; an $Al_xGa_{1-x}As$ layer of the gradient composition $x = 0.05 - 0.53$ and thickness $d = 0.5$ μm; an *N* emitter $Al_{0.49}Ga_{0.51}As$:Si with $n = 8 \times 10^{17}$ cm^{-3} and $d = 2.5$ μm; an $Al_{0.3}Ga_{0.7}As$ waveguide layer with $d =$ 0.15 μm; the first active GaAs layer with $d = 8.5$ nm; an $Al_{0.3}Ga_{0.7}As$ barrier layer with $d = 15$ nm; the second active GaAs layer with $d = 8.5$ nm; an $Al_{0.3}Ga_{0.7}As$ waveguide layer with $d = 0.15$ μm; an *P* emitter $Al_{0.49}Ga_{0.51}As$: Zn with $p = 4 \times 10^{18}$ cm^{-3} and $d =$ 1.7 μm; and a p^+ – GaAs contact layer with $p = 2 \times 10^{19}$ cm^{-3} and $d = 0.5$ μm.

Lasers with a mesastripe of width $w = 100$ μm were fabricated. The current limitation was created by healing with a high-resistance ZnSe layer of thickness 0.4 μm. On both surfaces of the heterostructure, ohmic contacts Ti/Ni/Au on the *p*-side and Ge/Au on the *n*-side were created. The structures were cleaved into crystals with the cavity length 800 μm. Dielectric multilayer coatings with reflectivities 10 and 95 % (for the front and back faces, respectively) were deposited on the laser diode faces, after which the crystal was mounted on a heat sink.

We studied output light – current and spectral characteristics of the laser diodes, as well as the divergence of their radiation in the far-field zone. In addition, we performed operating life tests for the lasers.

3. Results of measurements

Fig. 1 shows the typical watt-ampere characteristic of the laser at room temperature. The threshold current density was 420 A cm^{-2}, and the external differential quantum

A V Aluev, A M Morozyuk, M Sh Kobyakova, A A Chel'nyi Federal Unitary State Enterprise, M F Stelmakh Research Institute 'Polyus', ul. Vvedenskogo 3, 117342 Moscow, Russia

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efficiency was 84 % (1.2 W A^{-1}). The maximum cw power was 3.5 W and was limited by crystal heating. Catastrophic degradation during laser pumping by 150-ns current pulses with a repetition rate of 1 kHz occurred for a pulse power of 35 W. The characteristic temperature T_0 was 230 K, and the series resistance of the diodes was 0.1 Ω.

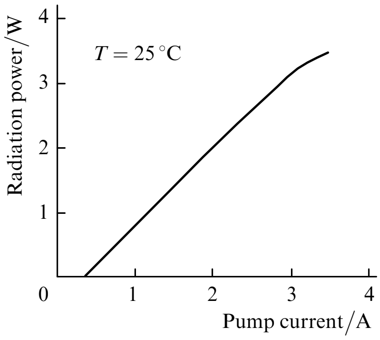

Figure 1. Typical watt-ampere characteristic of a laser at room temperature.

Relatively high power densities were obtained under the conditions of strong optical confinement of a light wave in the heterostructure waveguide. One can see from Fig. 2 that the beam divergence in a plane perpendicular to the plane of the $p-n$ junction was 40°.

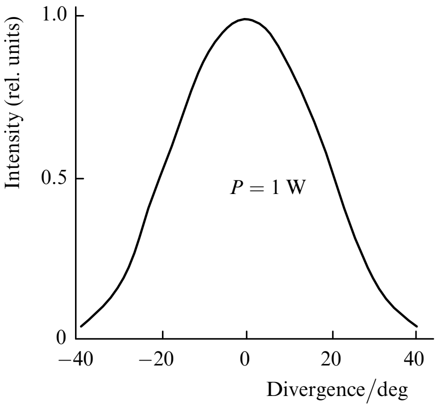

Figure 2. Beam divergence in the far-field zone in a plane perpendicular to the $p-n$ junction plane.

The high values of the characteristic temperature T_0 and the external differential quantum efficiency suggests that a leakage current of carriers from the active region is low. This is due to a high level of doping of the P emitter with zinc. The concentration of holes in the P emitter was 4×10^{18} cm^{-3}, which is 4–5 times higher than their concentration P emitters made of traditional structures.

The decrease in the series resistance of the lasers and an enhancement of carrier injection into the active region improved the spectral characteristics of lasers. Fig. 3 shows the emission spectrum of laser diodes for an output power of 1 W. The half-width of the emission line is 1.5 nm, and almost single-frequency lasing is observed.

Note that the high concentration of Zn in the emitter did not increase the optical losses in the cavity, the losses being 1–2 cm^{-1}.

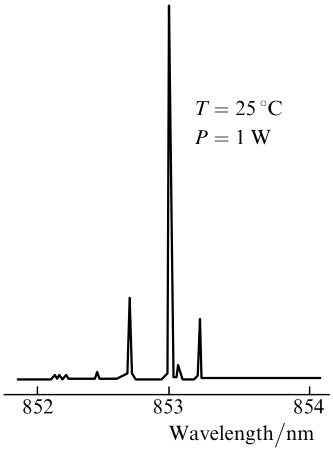

Figure 3. Emission spectrum at room temperature for an emission power of 1 W.

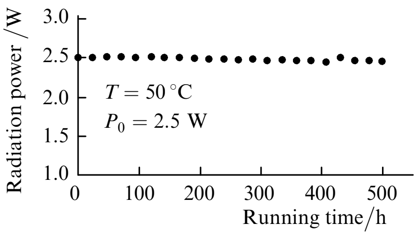

Figure 4. Results of operating life tests of lasers for the initial output power $P_0 = 2.5$ W at $T = 50\,^{\circ}$C.

Fig. 4 shows the results of operating life tests of the emitters. Studies were carried out at a heat sink temperature of 50 °C for 500 hours at constant pump current. The predicted design service life was more than 5×10^3 h.

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