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High-power 850 – 870-nm pulsed lasers based on heterostructures with narrow and wide waveguides

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Abstract. **The power and spectral characteristics of pulsed laser diode arrays operating in the spectral range of 850 – 870 nm and based on heterostructures of two different types (with narrow and wide waveguides) are studied. It is found that the power – current characteristics of the laser arrays of both types are linear within the pump current range of 10 – 50 A and that the steepness of these characteristics decreases at currents exceeding 80 A. The decrease in the slope efficiency is more noticeable for laser arrays based on heterostructures with wide waveguides.**

Keywords: *laser diode array, MOVPE, heterostructure, heat generation.*

1. Introduction

Semiconductor lasers emitting in the spectral range of 850 – 870 nm have found wide application in devices for various purposes, including traffic remote control systems [1]. The latter must reliably operate under different climatic conditions and require high energy characteristics of lasers, namely, the average pulse power must be no lower than 500 W. The needed pulse power can be achieved by summing the powers of individual laser diodes (LDs) and their bars, i.e., by using compact multi-element laser arrays [2]. At the same time, the array luminous body is desirable to be minimal, because of which LDs in the array must be positioned uniformly with the minimum distance between them. However, the high density of laser diodes in these arrays makes it difficult to achieve required laser power and wavelength due to intense heat generation.

In this work, we study the overheating of well InGaAs/AlGaAs/GaAs heterostructure (HS) laser diode arrays (LDAs) operating in the spectral range of 850 – 870 nm under different current pumping regimes.

2. Experimental

The well InGaAs/AlGaAs/GaAs HSs were grown by MOVPE at a reduced pressure in a Sigmos-130 horizontal quartz reactor with a graphite rotating substrate holder. Triethylgallium, trimethylindium, and trimethylaluminium were used as the sources of group III elements, while 100 percent arsine was used as a source of group V elements. Silane served as a source of the n-type dopant, and the sources of the p-type dopant were carbon tetrachloride and diethylzinc. As the carrier gas, we used hydrogen with a dew point of –100 ÷ –110 °C.

The chosen regimes of epitaxial growth allowed us to grow materials with a high structural perfection and a low background impurity concentration, which is necessary for creating devices with improved output parameters [3]. An additional measure to decrease the internal loss in HSs was profiled doping of emitter layers [4].

The HSs with a vertical beam divergence of 20° were designed in two types, with narrow or wide waveguides (Fig. 1).

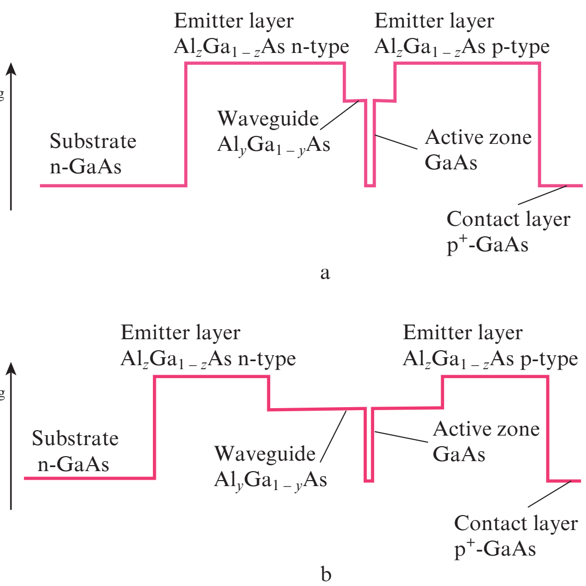

Figure 1. Schematic band diagram of separate optical and electron confinement HSs with (a) narrow and (b) wide waveguides.

Based on the grown HSs of the two types, we made lasers (arrays) 1 × 1 mm in size with a cavity length of 1000 – 1500 μm and reflection coefficients of the front and rear mirrors of 3%–7% and 95%, respectively. The output characteristics were measured at a current pulse repetition rate up to 10 kHz and a pulse duration up to 250 ns.

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3. Results and conclusions

One of the necessary requirements imposed on lasers in many practical applications is, in addition to a higher output power, a low beam divergence. Since the angular aperture of convex lenses in most cases is ~30°, it is preferable to use such laser HS designs at which the angular divergence is ~20°, which allows concentration of high power in a given angle.

Calculations show that the required angular divergence can be achieved using two geometries of separate optical and electron confinement HSs differing only by waveguide widths, i.e., HSs with narrow (0.2–0.3 μm) (type A) and wide (1.5–1.7 μm) (type B) waveguides [5].

The idea of wide waveguide is well known in the literature; these waveguides were used in different spectral regions (from 808 to 1060 nm). The main advantage of these waveguides, which makes it possible to achieve high radiation powers, is ultra-low internal optical loss [6, 7].

Comparison of lasers based on the A- and B-type HSs shows that the former have noticeably higher optical loss, but simultaneously are characterised by lower threshold currents and a lower (approximately by 10%–20%) electric series resistance.

We compared the output characteristics of stacked lasers based on both HS types.

A stack element of an LDA is an LD bar, because of which, at the first stage, we studied the power and electric characteristics of laser diode bars.

The output characteristics of LD bars 1 mm long (with 6–9 individual diodes in the bar) based on HSs of both types were found to be almost identical, the power–current characteristics (PCCs) being the same both at low (5–20 A) and high (~80 A) currents. Typical PCCs are shown in Fig. 2. The threshold current was 5.5–6 A for LDs based on narrow waveguides and 7–7.5 A for LDs based on wide waveguides. The current–voltage characteristics of diode bars based on HSs of both types were also similar.

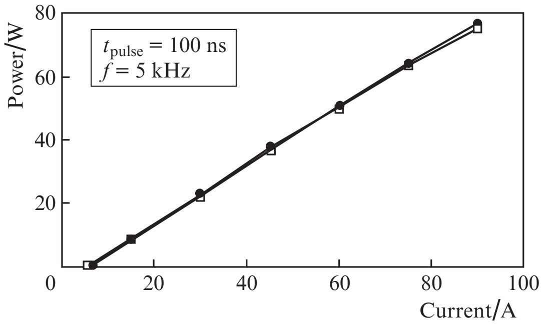

Figure 2. Power–current characteristics of laser bars based on HSs of the A (●) and B (□) types.

Noticeable differences in the output parameters were observe for LDAs with the number of laser bars from 10 to 14.

Within the pump current range of 10–40 A, the PCCs of laser arrays based on both HS types were linear. At a pump current of 40 A, a pump current pulse duration of 100 ns, and a repetition rate of 5 kHz, we observed no decrease in the slope efficiency η with respect to the initial value (Fig. 3). However, with increasing pulse repetition rate to 10 kHz or increasing pulse duration to 250 ns (at a current of 40 A),

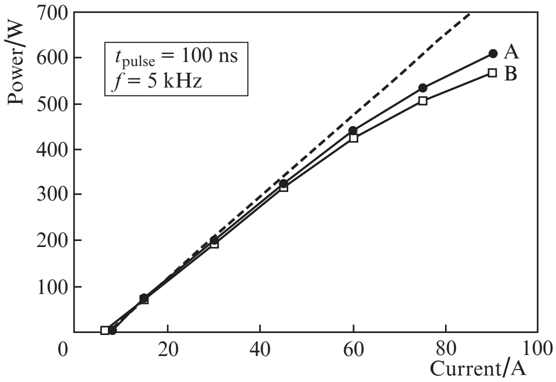

Figure 3. Power–current characteristics of laser arrays based on HSs of the A and B types.

the power decreased by 10–15 W. A further increase in the current (Fig. 3) led to a more pronounced decrease in η, the emission spectrum became broader, its maximum shifted to longer wavelengths, and, at a current exceeding 80 A, a decrease in the power reached 140 W.

All this clearly points to heating of LDAs. The main factors determining the decrease in the slope efficiency are an increase in the internal optical loss, an increase in the threshold current, and a difference in the electric and heat resistance of HSs with narrow and wide waveguides [8, 9].

The spectral characteristics shown in Fig. 4 allow us to estimate the heating temperature. The spectrum width at half maximum for the LDA based on the A-type HSs at a current

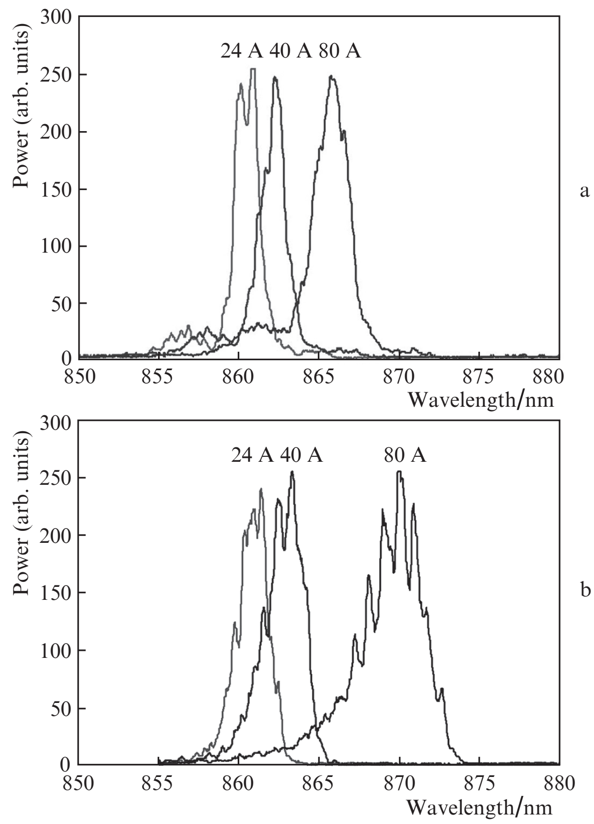

Figure 4. Emission spectra of LDAs based on InGaAs/AlGaAs/GaAs HSs of (a) A and (b) B types at different pump current pulse amplitudes.

of 24 A is only 2 nm, while the same value at a current of 80 A reaches 3 nm. At the same time, the spectral peak shifts by 5–6 nm, which, according to the known dependence [10], corresponds to an increase in the LD temperature by 10–15 K.

At the same pumping regimes, the spectral width at half maximum for the LDA based on the B-type HS increases at a current of 80 A to 6–7 nm, and the spectral maximum shifts even stronger, by 8–10 nm, which corresponds to the LD overheating by 30 K.

In our opinion, additional reasons responsible for the found differences in the output characteristics of compared lasers can be different temperature sensitivities of the threshold current (characterised by the T_0 parameter) and of the internal slope efficiency (characterised by the T_1 parameter) for the structures with narrow and wide waveguides.

Thus, the results obtained in this work allow us to conclude that the arrays based on HS with a narrow waveguide are preferable for producing compact lasers with increased power and brightness due to lower heat generation.

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