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Compact laser diode array based on epitaxially integrated AlGaAs/GaAs heterostructures

M.A. Ladugin, T.A. Bagaev, A.A. Marmalyuk, Yu.P. Koval',
V.P. Konyaev, S.M. Sapozhnikov, A.V. Lobintsov, V.A. Simakov

Abstract. **The main results of the development of compact laser diode mini-arrays operating under 875-nm pulsed pumping are presented and the instrumental characteristics of these arrays are studied. Specific features of these sources, in addition to a high output power (~1.5 kW), are a narrow directional pattern (angular divergence 21°×8°) and a small emitting area (less than 1 mm^2). The use of serially integrated AlGaAs/GaAs MOCVD heterostructures with three emitting regions to develop laser diode arrays allowed us to improve their working parameters.**

Keywords: *laser diode array, MOCVD, integrated heterostructure.*

1. Introduction

At present, high-power pulsed semiconductor lasers emitting in the range of 850–900 nm are of great practical interest due to their application in range finding and object detection, free-space wireless communications, and modern devices for remote transport control. In most of these applications, laser sources must have simultaneously a high output power, a small angular divergence, and a high pulse repetition rate. The pulsed output power often should exceed 1 kW [1]. At the same time, it is desirable to have the emitting body as small as possible and the directional pattern with a small angular divergence not only along the slow axis but also along the fast axis, because this makes it possible to increase the radiation brightness and reduce the requirements to the optical system controlling the laser beam.

In the present work, which continues the studies published in [2], we present the results of the development of compact laser diode arrays (LDAs) based on epitaxially integrated AlGaAs/GaAs heterostructures (HS's) with three emitting regions and study their characteristics satisfying the aforementioned requirements.

2. Experiment and measurement results

A pulsed optical power exceeding 1 kW can be obtained by summing the powers of individual laser diodes (LDs) in one-dimensional bars or two-dimensional arrays [3]. In addition, multielement laser arrays can be made using well-proven integrated LDs with several emitting regions, which were developed previously for the spectral ranges of 800–1100 and 1500–2000 nm [4–6].

Since it is desirable to achieve not only a high output power but also an angular divergence of ~20° along the fast axis (in the direction perpendicular to the layers), we chose a heterostructure with a narrow waveguide. As was shown in [2, 7], this heterostructure has a higher temperature stability than the structures with a broad waveguide, which is especially important at high pump currents. In addition, the threshold current of LDs based of HS's with a narrow waveguide was approximately 25% lower than that of LDs based on HS's with a broad waveguide.

For our purpose, we fabricated GaAs/AlGaAs/GaAs quantum-well heterostructures with three emitting regions to use them for the development of compact LDAs. The epitaxially integrated structures were grown by MOCVD similar to [4]. The regimes of growth of epitaxial layers were chosen to obtain a material with improved luminescence characteristics, high structural quality, and low background concentration of impurities, which is necessary for fabricating devices with high output parameters.

Preliminary calculations showed that the use of narrow waveguides in HS's rather than of broad waveguides makes it possible to decrease the total HS width from 20 to 15 μm, which considerably simplifies the technological cycle of active laser element fabrication. The SEM image of the cleavage of the grown epitaxially integrated HS and its schematic are shown in Fig. 1.

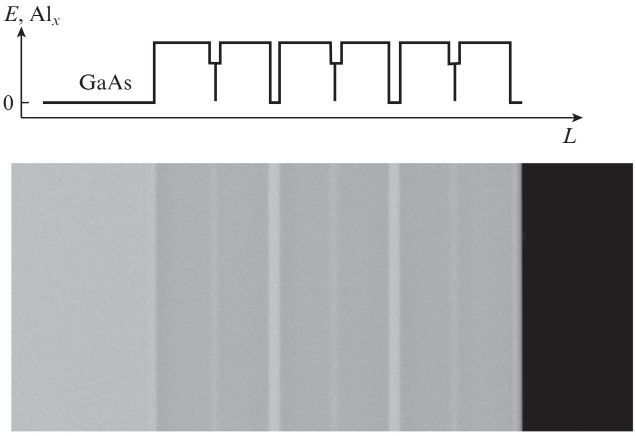

Figure 1. SEM image of the sample cleavage and schematic of the epitaxially integrated HS.

**M.A. Ladugin, T.A. Bagaev, A.A. Marmalyuk, Yu.P. Koval',
V.P. Konyaev, S.M. Sapozhnikov, A.V. Lobintsov, V.A. Simakov**
OJSC 'M.F. Stel'makh Polyus Research Institute', ul. Vvedenskogo 3, korp. 1, 117342 Moscow, Russia; e-mail: maximladugin@mail.ru

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On the basis of the grown HS's with three emitting regions, we fabricated laser arrays with different numbers of active elements and the total emitting area of about 1 mm^2 (Fig. 2). The LD cavity length was 1500 μm, and the reflection coefficients of the front and rear mirrors were 5% and 96%, respectively. The pump current pulse repetition rate varied during measurement of the output characteristics from 1 to 10 kHz, while the current pulse duration varied from 100 to 200 ns.

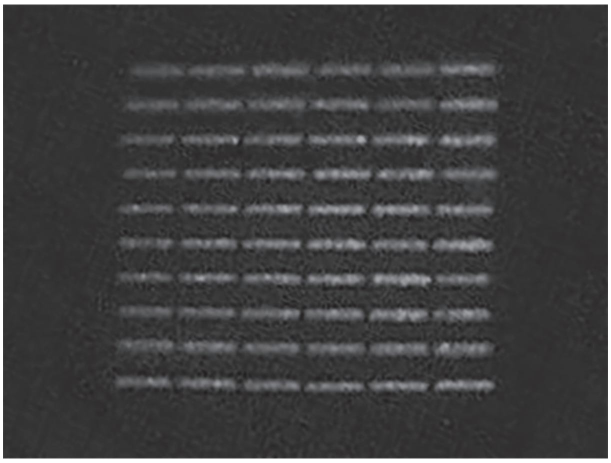

Figure 2. Typical near field of the LDA.

It is known that, due to a dense packing of laser elements in such LDAs, the required powers and wavelengths can be difficult to obtain due to a high heat release.

It is found that the light–current characteristics of the laser array (Fig. 3) in the pump current range of 10–40 A at a pulse duration of 100 ns and a repetition rate of 1 kHz was almost linear with a slope of ~23 W A^{-1}. However, at a pump current of 50 A, which corresponds to a power of ~1 kW, this characteristic begins to deviate from the linear dependence. As the pump current increased to 100 A, we observed a considerable (by 300–400 W) decrease in power with respect to the initial linear light–current characteristic, as well as a long-wavelength shift of the maximum and a broadening of the emission spectra. With increasing pulse repetition rate to 6 kHz or increasing pulse duration to 200 ns, the laser power decreased by 15%.

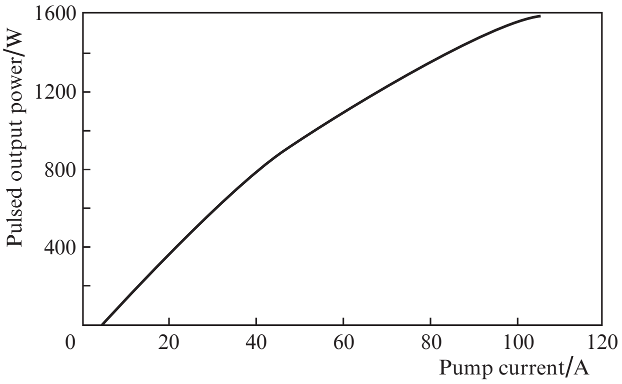

Figure 3. Light–current characteristic of the LDA based on the epitaxially integrated AlGaAs/GaAs HS.

All this testifies to self-heating of the LDA consisting of numerous individual emitting laser channels. The main reasons for a decrease of the slope of the light–current characteristic are a decrease in the quantum efficiency and an increase in the threshold pump current and internal optical losses [8].

The emission spectra measured at different pump currents (Fig. 4) clearly show that the maximum laser wavelength shifts approximately by 6 nm as the pulse amplitude changes from 10 to 100 A. This, according to the well-known temperature dependence of the LD band gap [9], corresponds to an increase in the LDA temperature by approximately 15–20 °C.

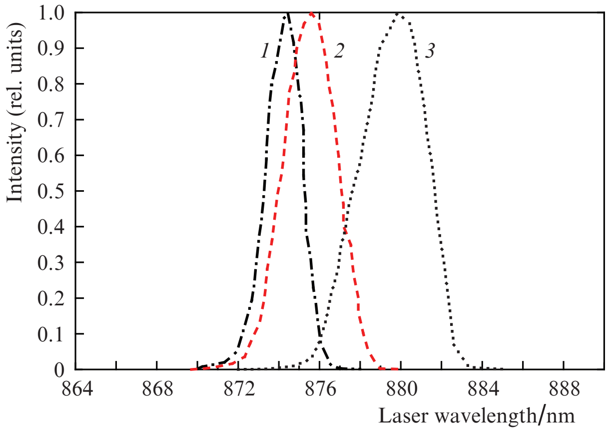

Figure 4. Spectra of the LDA based on the GaAs/AlGaAs/GaAs HS at pump current pulse amplitudes of (*1*) 10, (*2*) 50, and (*3*) 100 A.

Simultaneously, the spectral FWHM increases by 1–1.5 nm, but still remains sufficiently narrow and acceptable for most practical applications.

In this work, we additionally performed lifetime tests of LDAs at room temperature with a pump current pulse (5 kHz, 100 ns) amplitude corresponding to an output power of 1 kW. After 4×10^9 pulses, the output power decreased with respect to the initial value by no more than 8%.

3. Conclusions

Thus, we demonstrated the possibility of creating reliable compact lasers based on AlGaAs/GaAs semiconductor heterostructures emitting within the range of 870–890 nm. High power characteristics with a small (about 1 mm^2) emitting area (P_p > 1.5 kW at a pump current of 100 A) can be obtained only using structures with several emitting regions grown successively one after another by MOCVD. Despite heating of the LDA at high pump currents, the emission spectrum had a small (~3 nm) width, while the divergence along the fast axis was only 21°.

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