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1.5 to 1.6 μm pulsed laser diode bars based on epitaxially stacked AlGaInAs/InP heterostructures

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Abstract. **This paper describes 1.55-μm pulsed laser diode bars based on epitaxially stacked double AlGaInAs/InP heterostructures. The output power of such bars is 1.8 times that of single-heterostructure laser diode bars. We present the key characteristics of the laser sources.**

Keywords: *metal-organic vapour phase epitaxy, laser diode bars, epitaxial stacking.*

1. Introduction

Pulsed sources emitting in the spectral range 1.5 to 1.6 μm have a lower output power [1 – 5] than do shorter wavelength devices with $\lambda = 0.7 - 1.1$ μm, but human eye safety and atmospheric transparency make such sources attractive for many applications. One possible way of raising the output power of laser sources is by using multielement laser diode bars (LDBs) and two-dimensional laser diode arrays (LDAs) instead of single LDs [6 – 9]. The use of such sources may be limited by the dimensions of their emitting region and the contact resistance between the array elements. Moreover, LDA fabrication requires the use of solder, which impedes heat removal and increases the production time and cost of the device. In view of this, a promising approach is the integration of emitting regions during epitaxial growth by means of a tunnel junction [8, 10 – 16]. The most serious problem in creating such heterostructures (HS's) is the ability to design and optimise their geometry and minimise the mechanical stress in the multilayer structure.

The ability to produce a degenerate tunnel junction between emitting regions is of key importance in the fabrication of HS's for integrated LDs because the tunnelling current across such junctions is extremely sensitive to both the p- and n-type doping levels [13]. Since such devices are very difficult to produce, the design and fabrication of epitaxially stacked HS's and related LDs require taking into account a considerably greater number of process variables. At the same time, owing to the potential advantages of epitaxially stacked LDBs there is currently an obvious need for this approach.

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2. Description of LDBs

Heterostructures were grown by metal-organic vapour phase epitaxy in a horizontal slit-type quartz reactor. We studied two types of HS's: single and double. The latter consisted of two identical HS's connected by a tunnel junction. The single HS design was based on the concept of broad asymmetric waveguide [17].

The double HS design was calculated so as to minimise the penetration of the fundamental mode into the heavily doped region of the tunnel junction. To this end, we used a broad AlGaInAs waveguide, and the InP emitter layers had a gradient doping profile. The waveguide layer composition was chosen so as to ensure a high degree of electron confinement in the quantum wells.

The HS's were used to fabricate five-element LDBs. The laser cavity was 2 mm long, and the contact to each element was 100 μm wide. The facets had 5% and 95% reflecting coatings. The LDBs were mounted, with their epitaxial side down, on a copper heat sink.

3. Experimental results

The emission characteristics of the LDBs were investigated at a pulse duration of 100 ns and pulse repetition rate of 5 kHz. For comparison, we fabricated a typical LDB having one emitting region of similar geometry.

Figure 1 shows the current – voltage ($I - V$) curves of the LDBs having one and two emitting regions. The LDBs differed in threshold voltage by a factor of 2.1, suggesting that the tunnel junction had a low series resistance. Typical threshold voltages of the single and stacked LDBs were 0.8 and 1.67 V, respectively. Such $I - V$ behaviour is characteristic of LDs having several emitting regions and was observed in analogous shorter wavelength devices [8, 12, 16].

The light power – current ($L - I$) curves of the LDBs are presented in Fig. 2. The threshold current for lasing in typical single LDBs was 3.8 – 4.4 A and that in the double LDBs was 5 – 7 A. The higher threshold current in the double LDBs was probably due to differences in the formation of active emitting regions. The larger thickness of the double HS in the AlGaInAs – InP system may lead to elastic stress build-up during growth, modifying the nominal profile of the quantum wells and distorting their band structure. Thus, sequentially produced active regions may differ, which is responsible for the observed increase in lasing threshold.

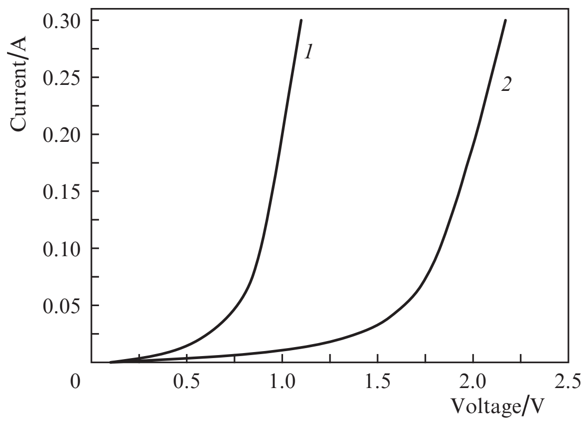

Figure 1. Current–voltage curves of the LDBs having (*1*) one and (*2*) two emitting regions.

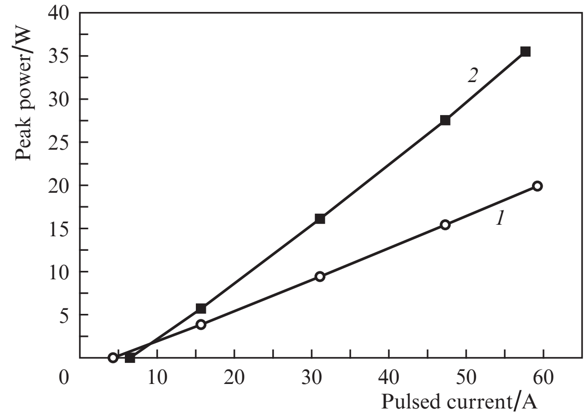

Figure 2. Power–current curves of (*1*) a single LDB and (*2*) stacked LDB.

Above the lasing threshold, the slope efficiency of the stacked LDBs was 1.8 times that of the single LDBs. A typical slope of the power–current curve was 0.36 W A^{-1} for the single LDBs and 0.69 W A^{-1} for the double LDBs. The highest output power attained at a pump current of 60 A was 20 W for the single LDBs and 36 W for the double LDBs. No thermal rollover was observed in the $L-I$ curves of the LDBs in the range of pump currents studied, which suggests that their output power can be raised further.

Figure 3 shows the emission spectrum of a double-HS LDB. The full width at half maximum of the spectrum is 7–8 nm, which slightly exceeds that of a typical single LDB (4–6 nm). One possible cause of the observed broadening of the spectrum is the above assumption that the two emitting regions differ in geometry.

Thus, we obtained epitaxially stacked double HS's and LDBs based on them. At a pump current of 60 A, the peak pulse power was increased from ~20 W (typical output power of a single LDB) to 36 W (double LDBs). Epitaxial stacking of LDs in the spectral range 1.5 to 1.6 μm is a viable alternative to two-dimensional laser diode arrays, offers a number of advantages and allows one to reach excellent output characteristics at limited emitting region dimensions.

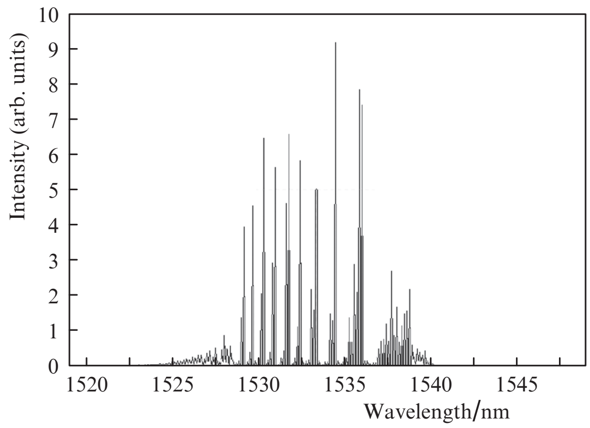

Figure 3. Emission spectrum of a stacked-HS LDB.

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