Continuous-wave operation of GaInNAsSb distributed feedback lasers at 1.5 μm

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GaAs-based singlemode emission at 1.5 μm has been realised for the first time in continuous-wave operation. GaInNAsSb active-layer material and GaAsN strain-compensating barriers have been used in combination with lateral distributed feedback. Laser diodes with a threshold current of 95 mA, an external efficiency of 0.15 W/A and a maximum output power of more than 10 mW could be demonstrated. A sidemode suppression ratio better than 31 dB could be realised at a singlemode emission wavelength of 1496 nm.

Introduction: The material systems GaInNAs(Sb) have recently attracted much interest due to their potential to realise GaAs-based emission in the 1.3 and 1.55 μm region. GaInNAs-based continuous-wave (CW) and pulsed operation has been reported up to 1.42 and 1.5 μm, respectively [1, 2]. Using GaInNAsSb, CW operation at 1.5 μm could be realised [3]. Using the concept of complex gain-coupled distributed feedback (DFB) lasers based on lateral metal gratings [4] and epitaxial material with an improved quantum well design employing GaAsN strain-compensating barriers [5], we have realised pulsed singlemode operation in the 1.5 μm range [6]. Here we report results on GaAs-based singlemode DFB lasers with GaInNAsSb active region and emission wavelengths at 1.5 μm under CW operation.

Growth and structure: The lasers were grown on a (1 0 0) *n*-type GaAs substrate by solid-source molecular beam epitaxy [3]. Reactive nitrogen was supplied by an RF plasma cell operating in the inductively coupled mode with 300 W of input power and a gas flow of 0.5 sccm. Nitrogen concentration was controlled directly by the group III growth rate [7]. Antimony was supplied with an unvalved cracking cell, producing almost entirely monomeric antimony. The beam equivalent pressure was $\sim 1 \times 10^{-7}$ Torr and resulted in an antimony mole fraction of 2.7% in the quantum well. GaInNAsSb and GaAsN were grown at 455°C with 20× and 15× arsenic overpressures, respectively. (Al)GaAs layers were grown at 20°C above the oxide desorption temperature with 15× arsenic overpressure. The single QW active region was a 75 Å $Ga_{0.62}In_{0.38}N_{0.023}As_{0.95}Sb_{0.027}$ well surrounded on either side by 220 Å strain-compensating $GaAs_{0.975}N_{0.025}$ barriers. The active layer was surrounded on either side by 2000 Å of GaAs and 1.8 μm of $Al_{0.33}Ga_{0.67}As$. To minimise free carrier absorption losses, doping of the AlGaAs was kept low close to the GaAs/AlGaAs interface. The outer 9000 Å of the *n*-type cladding layer was doped at 3×10^{18} cm^{-3} and the inner 9000 Å doped at 7×10^{17} cm^{-3}. The *p*-type cladding was a similar structure, with the inner 9000 Å doped at 5×10^{17} cm^{-3} and the outer 9000 Å doped at 3×10^{18} cm^{-3}. The structure was capped with a 500 Å $\sim 1 \times 10^{20}$ cm^{-3} *p*-type GaAs contacting layer.

Fabrication: After growth, the sample was *ex situ* annealed under a GaAs proximity cap at 800°C for 1 min in a nitrogen ambient. Ti/Pt/Au ohmic contacts were patterned with evaporation and lift-off. Ridges with widths between 5 to 20 μm were defined by a self-aligned dry etch to the top of the GaAs waveguide. The substrate was thinned and Au/Ge/Ni/Au ohmic contacts were evaporated and annealed at 415°C for 30 s. A selected batch of the ridges was processed further into DFB lasers with dimensions of 800×3 μm^2. The processing technique used has been described in detail in [8]. For CW measurements the lasers were mounted epi-side up on standard TO 5.6 mm copper headers using a Pb-Sn soldering process.

Results: The DFB lasers were investigated in CW operation. Fig. 1 shows the light output against drive current (L-I) characteristics of a laser at 10°C. The threshold current is 95 mA with an external efficiency of 0.15 W/A per facet. The maximum output power from both facets exceeds 10 mW. At an operation temperature of 15°C (20°C) the corresponding values are 103 mA (112 mA) for the threshold current, 0.11 W/A (0.098 W/A) for the external efficiency per facet and 5 mW (2 mW) for the overall maximum output power. As we have observed a large increase in performance compared to the unmounted laser bars we would expect a further performance leap by applying a more sophisticated mounting process, e.g. epi-side down mounting.

The spectrum of the 800×3 μm^2 DFB laser diode can be seen in Fig. 2. At an operating temperature of 15°C and at a drive current of 120 mA the singlemode emission wavelength is 1496.5 nm. The corresponding output power is 2 mW per facet under these conditions. The sidemode suppression ratio (SMSR) is larger than 31 dB. It is limited by one single sidemode only and shows the potential for >40 dB SMSR. Careful control of the ridge-width and etch-depth could further suppress this single sidemode as they control the coupling of the lightwave to the lateral grating.

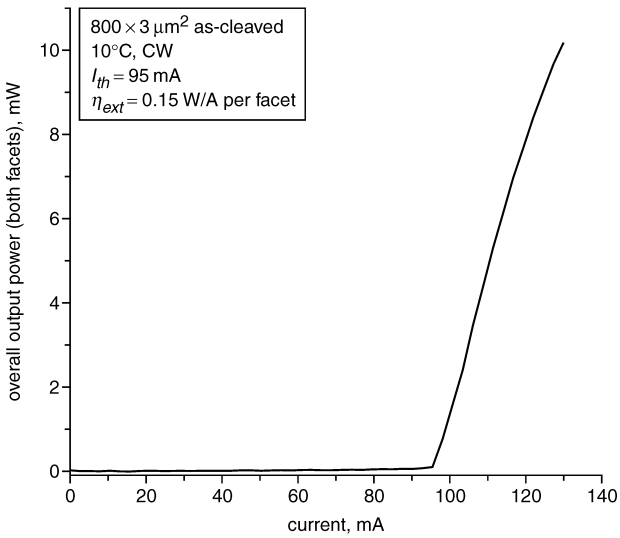

Fig. 1 *L-I curve of as-cleaved 800 × 3 μm² DFB laser in CW operation at 10°C*

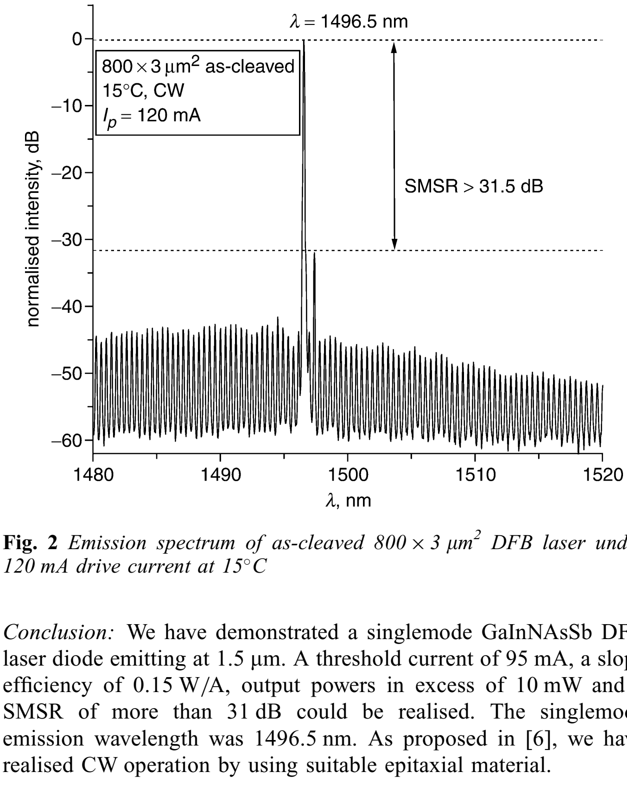

Fig. 2 *Emission spectrum of as-cleaved 800 × 3 μm² DFB laser under 120 mA drive current at 15°C*

Conclusion: We have demonstrated a singlemode GaInNAsSb DFB laser diode emitting at 1.5 μm. A threshold current of 95 mA, a slope efficiency of 0.15 W/A, output powers in excess of 10 mW and a SMSR of more than 31 dB could be realised. The singlemode emission wavelength was 1496.5 nm. As proposed in [6], we have realised CW operation by using suitable epitaxial material.

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