Design and growth of GaAsBi and InGaAs based Vertical-External-Cavity Surface-Emitting-Lasers

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Vertical-External-Cavity Surface-Emitting Lasers (VECSELs) have emerged as a versatile alternative to traditional Vertical-Cavity Surface-Emitting Lasers (VCSELs) by replacing the top Distributed Bragg Reflector (DBR) with an external coupler, enabling efficient optical pumping and cavity access. This design offers higher output power potential, constrained primarily by thermal management challenges [1, 2].

In this work, two VECSEL chips were fabricated, targeting emission wavelengths of 976 nm and 1070 nm. The 976 nm VECSEL employed InGaAs multiple quantum wells (MQW) in the gain region, while the 1070 nm VECSEL utilized GaAsBi MQW. Incorporation of Bi in the GaAs lattice reduces the bandgap faster than In. This also improves bandgap temperature stability, and increases the spin-orbit split-off energy, mitigating non-radiative Auger recombination, and making GaAsBi an attractive material for long-wavelength optoelectronic devices.

Both MQW structures were grown via solid-source Molecular Beam Epitaxy (MBE) using a Veeco GENxplor system. The DBR, comprised 30 AlAs/GaAs periods, was designed to centre the MQW emission within the photonic stopband. A gain region with 12 QWs and alternating barrier thicknesses, shown in Figure 1, was adopted to reduce the chip total thickness and improve thermal management. The thicknesses of the barrier were calculated to align the antinodes of the lasing standing wave with the position of the QWs allowing for coupling of enhancing emission.

In the InGaAs based chip the thickness of the QW was 5.7 nm with an indium content of 20% and barrier of 7 nm. The pairs of QWs were separated by 98 nm thick-barrier. While in the gain region based on GaAsBi the QW thickness was 5.5 nm with a bismuth content of around 8% and alternating barrier thicknesses of 7 nm and 150 nm.

Lasing was successfully demonstrated from the InGaAs/GaAs MQW VECSEL at 976 nm, with emission from a 500 μm diameter region. The lasing from the GaAsBi/GaAs MQW VECSEL was observed at 1070 nm, marking the first reported instance of lasing from a GaAsBi based VECSEL. Lasing characteristics of bismide VECSEL presented in the Figure 2.

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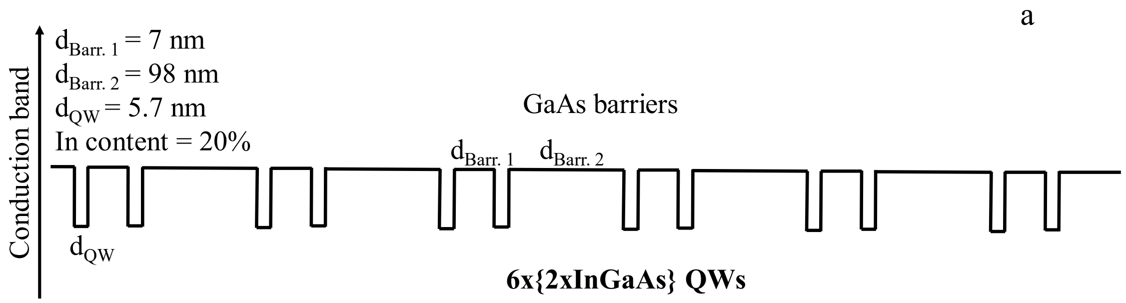
[1] Muszalski Jan, et al., "VECSELs emitting at 976nm designed for second harmonic generation in the blue wavelength region", Proc. SPIE 8702, Laser Technology 2012: Progress in Lasers, 87020A (2013).

[2] Jacquemet Mathieu, et al., "Single-frequency cw vertical external cavity surface emitting semiconductor laser at 1003 nm and 501 nm by intracavity frequency doubling", Applied Physics B, 86(3), 503-510 (2007).



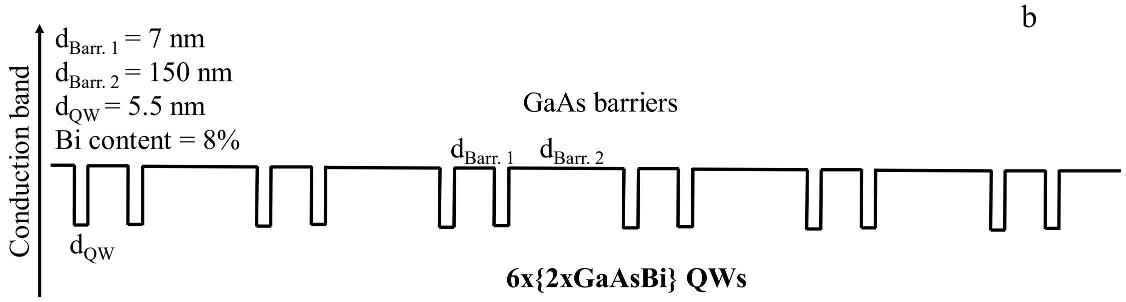


Figure 1: Conduction band scheme of the grown active areas:

a) InGaAs based active area; b) Gain region based on GaAsBi MQW

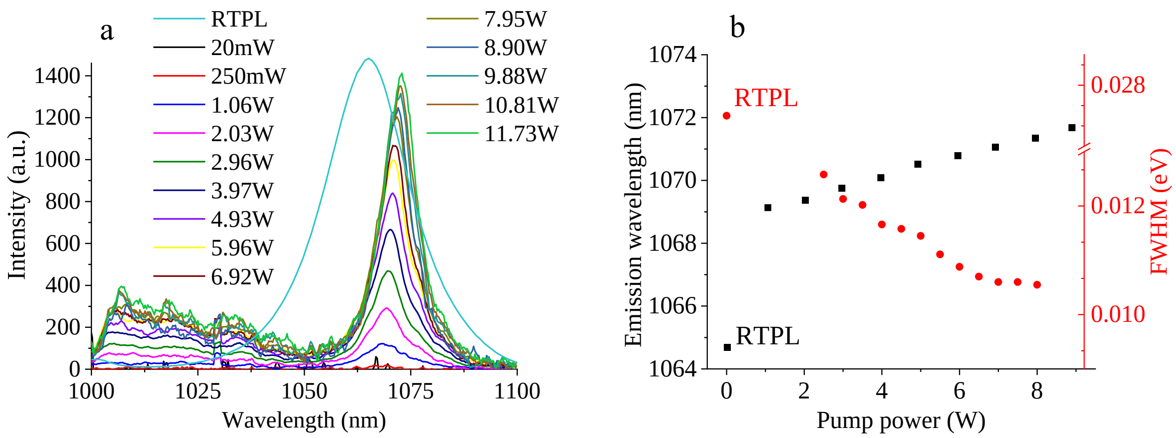


Figure 2: Lasing measurements of the GaAsBi based VECSEL:

a) Lasing spectra at different pumping powers, from PL to lasing;

b) The emission wavelength dependence on pumping power on the left in black,

full width at half maximum (FWHM) in red on the right.