Continuous Wave Operation of InAs/AlSb QCLs

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BIOGRAPHY

Pierre Laffaille is currently a PhD student in the NANOMIR group of the IES laboratory of the University of Montpellier 2, Montpellier, France. He is working on the development of mid-infrared InAs/AlSb quantum cascade lasers. In particular, he fabricated and studied distributed feedback InAs-based QCLs operating between 3 and 4 µm. The main goal of his PhD work is the realization of mid-infrared QCLs in this material system operating in the continuous wave regime at room temperature.

TECHNICAL ABSTRACT

The InAs/AlSb material system is well suited for short wavelength quantum cascade lasers because of the high conduction band offset between InAs and AlSb and the large separation of direct and indirect minima in the conduction band of InAs. These materials are also attractive for long wavelength QCLs because of the small electron effective mass in InAs which should provide high intersubband gain. QCLs emitting at wavelengths as short as 2.6 µm have been demonstrated in this system [1]. InAs-based QCLs emitting above 3 µm operate in pulsed mode up to temperatures exceeding 400K with threshold current densities about 3 kA/cm² at room temperature (RT)[2]. Heavily doped n+ InAs cladding layers are used in these lasers for optical confinement. Low doped InAs/AlSb superlattice spacers separate the QCL active zone from the highly absorbing claddings. The active zone contains 25-30 repetitions of the layer sequence designed using the bound-to-continuum QCL scheme with vertical transitions. The operating voltage of such short wavelength QCLs exceeds 15 V because of the high photon energy. The high operating voltage and poor thermal dissipation due to the thick superlattice spacers make difficult to achieve continuous wave (CW) operation of InAs-based QCLs at the current state of maturity of this material system. In order to realize the CW regime of operation we tried to improve thermal conductance and to decrease the operating voltage of the devices.

These improvements can be easier achieved in the lasers emitting at long wavelengths. The superlattice spacers can be replaced by low doped InAs with higher thermal conductivity in the QCLs operating above 4 µm. The operating voltage can also be significantly reduced in QCLs with small photon energy. We studied InAs/AlSb QCLs emitting near 9 µm with InAs spacers and a 35-period active zone. Ridge lasers have been fabricated from the MBE grown wafer by conventional photolithography and wet etching. Hard-baked photoresist was used for electrical insulation. 3.6-mm-long and 12-µm-wide QCLs were mounted epi-side down onto copper heat sinks. The voltage at threshold was 7.1V at 80K and 6.5V at RT for these devices. The lasers operated in pulsed mode (100ns, 10 kHz) up to 400K with a room temperature threshold current density of 2.7 kA/cm². The CW regime has been obtained up to 255K (Fig.1). The thermal resistance of the devices estimated from the obtained data is 8 K/W.

The operating voltage of short wavelength QCLs can be reduced in structures with a smaller number of cascades. The QCL gain which depends on the number of cascades will also be reduced resulting in higher threshold current density. On the other hand, the electrical power to dissipate can be lower in a laser with such active zone due to the better optical confinement for the QCL stages located in the center of the waveguide. Another advantage of the reduced thickness of the active zone is an improvement in the thermal conductivity of the QCL structure. We fabricated and studied InAs/AlSb QCLs emitting at 4.7 µm with 30 and 15 cascades in the active zone using the same processing technology as for the 9 µm devices. The threshold voltage of the 15-stage QCLs was 5.2V at RT, 1.9 times lower than that of the lasers with the thicker active zone, while the increase in the threshold current density was less significant. The RT threshold current density was 3.05 and 4.0 kA/cm² for the 30- and 15-stage lasers, respectively. The maximum
pulsed operation temperature of the 15-stage QCLs decreased to 340K compared with 400K for the 30-stages devices. They exhibited however higher operation temperatures in the CW regime reaching 240K (Fig.1). The thermal resistance of these 8-µm-wide lasers was estimated to be 6 K/W from the comparison of the threshold current densities in the CW regime and in pulsed mode.

![Graph](Fig.1. Threshold current density of InAs/AlSb quantum cascade lasers with HR-coated back facets as a function of temperature.)

In order to increase the CW operation temperature of InAs/AlSb QCLs up to RT and to achieve this regime in lasers emitting at shorter wavelength it is necessary to reduce their threshold current densities to the level corresponding to the intrinsic properties of this material system. For this purpose it is necessary to decrease the internal loss of the waveguide and to improve its thermal conductivity. We will discuss different approaches for achieving this goal.

**References**


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