IQCLSW
2014

International Quantum Cascade Lasers School & Workshop

Policoro, Italy, 7-14 September 2014

QCLs: 20 years of discoveries
1994-2014

Various Barrier Materials for Terahertz Quantum Cascade Lasers

Tobias Zederbauer[1,*], Don MacFarland[2], Michael Krall[3], Hermann Detz[2], Aaron Maxwell Andrews[2], Werner Schrenk[1], Karl Unterrainer[3], and Gottfried Strasser[2]

[1] *Center for Micro and Nano structures, TU Wien, 1040 Wien, Austria*
[2] *Institute for Solid State Electronics, TU Wien, 1040 Wien, Austria*
[3] *Institute for Photonics, TU Wien, 1040 Wien, Austria*
[*] *tobias.zederbauer@tuwien.ac.at*

1 Introduction

Since their invention in 1994, quantum cascade lasers (QCLs) have proven to be reliable and highly customizable coherent light sources, which allow for the design of devices emitting in the mid-infrared (MIR), as well as in the terahertz (THz) regime. Despite their great success in the MIR regime, QCLs operating at THz frequencies still require cryogenic cooling techniques. Advanced band structure design recently pushed the maximum operation temperature of THz QCLs to 200 K[1]. Moreover, the use of symmetric active regions has shown the potential to measure the effects of both interface roughness and dopant migration on the performance of this devices[2][3]. Room temperature operation, however, is still out of reach to this date.

A second approach to further improve the performance of THz QCLs is to use other material systems. While the highest pulsed operation temperature so far has been measured from devices fabricated in the GaAs/AlGaAs material system, there is evidence that the use of well materials with a lower effective mass can improve the performance[4]. Candidates for well materials featuring an effective mass lower than that of GaAs are InGaAs lattice matched to InP, as well as InAs. Recently THz electroluminescence from devices using InAs as a well and AlAsSb as a barrier material was shown[5], despite the very low effective mass, no laser operation was reported.

In the group of materials lattice matched to InP, laser operation in the THz regime has been shown for three different material combination so far. The two ternary materials AlInAs and GaAsSb have shown THz laser operation up to 145 K and 143 K respectively[6]. The quaternary AlGaInAs material, being the most recently developed one among them, showed operation up to 130 K[7]. The fact that many different materials, all having unique features, can be used as a barrier material with the same well material makes this group of materials interesting to gauge the influence of the barrier material on the performance of THz QCLs.

2 Results

In this work, we show our first results of THz QCLs using the quaternary AlGaInAs material and report on our latest findings when comparing them to devices using different materials. The lasers have been grown in a Veeco Mod Gen II MBE system on InP substrates. Aluminum mol fractions of 15% and 18% have been used. The lasers have been processed into ridges using double-metal waveguides.

Both designs showed laser emission at 3.6 THz, a maximum operation temperature of 110 K and a threshold current density of 800 Acm^{-2}.

References

[1] S. Fathololoumi, E. Dupont, C.W.I. Chan, Z.R. Wasilewski, S.R. Laframboise, D. Ban, A. Matyas, C. Jirauschek, Q. Hu, and H. C. Liu, Optics Express 20, Issue 4, 3866 (2012)

[2] C. Deutsch, H. Detz, M. Krall, M. Brandstetter, T. Zederbauer, A. M. Andrews, W. Schrenk, G. Strasser, and K. Unterrainer, Appl. Phys. Lett. 102, (2013)

[3] C. Deutsch, H. Detz, T. Zederbauer, A. M. Andrews, P. Klang, T. Kubis, G. Klimeck, M. E. Schuster, W. Schrenk, G. Strasser, and K. Unterrainer, Appl. Phys. Lett. 102, (2013)

[4] E. Benveniste, A. Vasanelli, A. Delteil, J. Devenson, R. Teissier, A. Baranov, M. Andrews, G. Strasser, I. Sagnes, C. Sirtori, Appl. Phys. Lett, 93, (2008)

[5] K. Ohtani, M. Fischer, G. Scalari, M. Beck, and J. Faist, Applied Physics Letters 102, (2013)

[6] C. Deutsch, A. Benz, H. Detz, P. Klang, M. Nobile, A. M. Andrews, W. Schrenk, T. Kubis, P. Vogl, G. Strasser, and K. Unterrainer, Appl. Phys. Lett. 97, 261110 (2010)

[7] K. Ohtani, M. Beck, G. Scalari, and J.Faist, Applied Physics Letters 103, (2013)

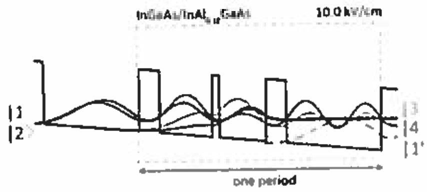

Figure 1: Band structure of a $Al_{0.18}GaInAs/InGaAs$ THz QCL at a bias of 10 kVcm^{-1}

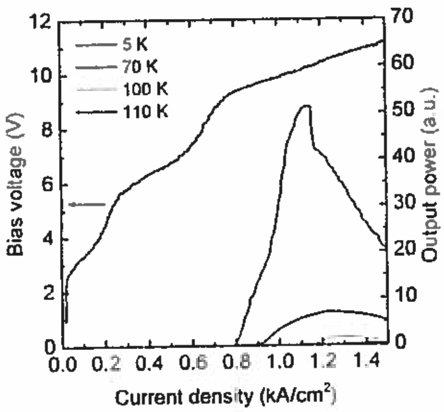

Figure 2: LIV of a $Al_{0.18}GaInAs/InGaAs$ THz QCL. At 5 K a threshold current density of 800 Acm^{-2} was found. Operation was possible up to 110 K