Improving Interband Cascade Laser Performance: Mitigating Valence Intersubband Absorption

H. Knötig [1], J. Nauschütz [2], N. Opačak [1], S. Höfling [3], J. Koeth [2], R. Weih [2] and B. Schwarz [1]

[1] *Institute of Solid State Electronics, TU Wien, Gusshausstrasse 25-25a, Vienna, Austria*
[2] *nanoplus Nanosystems and Technologies GmbH, Oberer Kirschberg 4, Gerbrunn, Germany*
[3] *Physikalisches Institut and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, Würzburg, Germany*

Interband cascade lasers (ICLs) [1] are gaining more and more attention from both researchers and in industry, as they constitute an ideal platform for novel integrated photonic sensors. Especially valued for their low threshold current densities and low power consumption, they qualify for a large variety of applications aiming for portable, miniaturized sensing systems. ICLs show a performance sweet spot around 3-4 µm and continuous-wave operation at room temperature has been shown at wavelengths from 2.8-5.6 µm in the GaSb material system. However, their performance notably degrades outside the 3-4 µm region.

Here, we present a solution to overcome current performance limitations.[2] First, using a numerical model employing the eight-band **k·p** method, we calculate the electronic band structure of the active W-quantum well (QW) in an ICL (Fig. 1a). Then we determine the wavelength-dependent absorption between subbands in the valence band for various $Ga_{1-x}In_xSb$ hole-QW thicknesses, using a generalized momentum matrix element model (Fig. 1b). Subsequently, we experimentally observe a clear performance dependence on the thickness of the hole-QW. Specifically, the threshold current density J_{th}, the characteristic temperature T_0, the slope efficiency and the output power show significant improvement. Extracted waveguide losses from length-dependent measurements further substantiate the key role of the valence intersubband absorption. While the performance improvement is experimentally verified at 4.35 µm, particularly relevant for isotopic abundance analysis of CO_2, our simulation results set a new guideline for ICL active region design, paving the way towards higher operating temperatures and output powers outside of the sweet spot 3-4 µm region by mitigating undesired absorption.

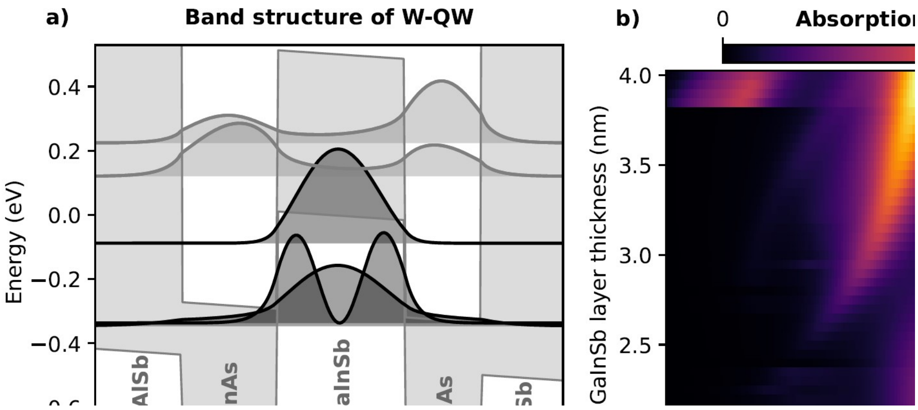

Fig. 1.a) Band structure of a W-QW at the Γ-point. b) Calculated valence intersubband absorption of the W-QW depending on the $Ga_{0.65}In_{0.35}Sb$ layer thickness.

[1] J. R. Meyer, et al., *Photonics* **2020**, 7(3), 75 (2020).
[2] H. Knötig, et al., *under review* (2021)