Multiband k·p Simulation of Confined States in Interband Cascade Lasers

T. Sato[1,2], B. Petrovic[3], S. Birner[1] and T. Grange[4]

[1] *nextnano GmbH, Konrad-Zuse-Platz 8, 81829 München, Germany,*
[2] *Department of Electrical and Computer Engineering, Technical University of Munich, Hans-Piloty-Straße, 85748 Garching b. München, Germany,*
[3] *Technische Physik, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Am Hubland, D-97074 Würzburg, Germany,*
[4] *nextnano Lab, 12 chemin des prunelles, 38700 Corenc, France*

Interband cascade laser (ICL) is a mid-infrared coherent optical source based on interband transition of charge carriers. Due to significantly lower threshold power density in comparison to its intersubband counterpart quantum cascade laser, ICL attracts attention as a light source for mid-infrared spectroscopy applications that do not require high output power but instead portability and/or possibility of battery operation [1]. Radiative transitions in ICLs take place in arsenic/antimonide-based quantum wells with either type-I or type-II band alignment. The energy dispersion in such structure have been calculated [2] as a function of layer thicknesses and/or material combinations.

While a large spatial overlap and carrier rebalancing in the heterostructure [1] are desired for a better ICL performance, multiband simulation of position-dependent quantities has yet to be intensively examined. Here, we calculate the confined states and charge densities in various active region designs using the 8-band **k·p** model in the nextnano++ software. The impact of the interband coupling and the choice of the material parameters are investigated. This study forms a basic tool for design optimization of ICLs in the thermal equilibrium. We also present our ongoing development of the nextnano.NEGF software, which will enable non-equilibrium quantum transport simulation of ICLs under bias.

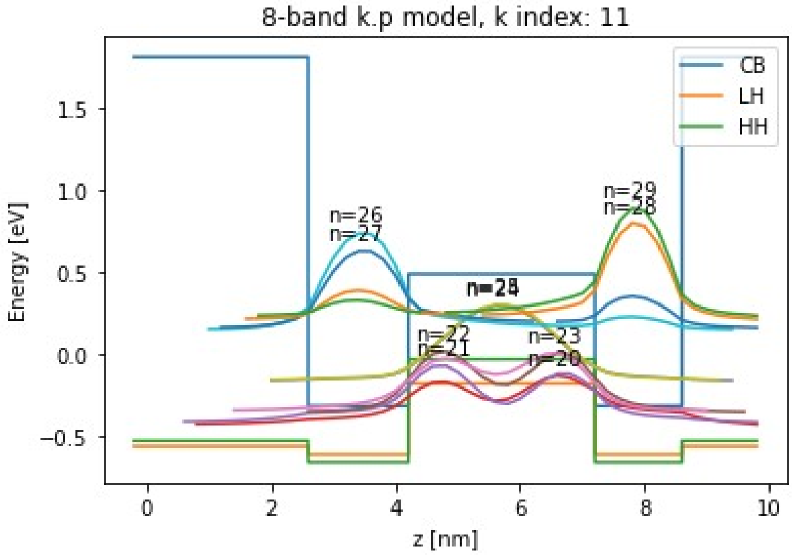

Figure: Eigenstate profiles at a non-zero in-plane **k** simulated by the nextnano++ software, superimposed on the conduction band (CB), light hole (LH) and heavy hole (HH) bandedges.

[1] I. Vurgaftman *et al*., *Nat. Comm.* **2**, 1-7 (2011); J.R. Meyer *et al*. *Photonics* 7, 75 (2020).
[2] C. Liu *et al*. Phys. Rev. Lett. **100**, 236601 (2008); K. Ryczko *et al*., J. Appl. Phys. **114**, 223519 (2013); S.S. Krishtopenko and F. Teppe, Sci. Adv. **4** (2018)