Carrier Dynamics in imperfect Quantum Cascade Structures

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The Quantum Cascade Lasers (QCL) are unipolar lasers that emerged in the mid 1990, thanks to the conjunction of mastered growth and bandgap engineering [1]. Besides the QCL's, a number of optical devices based on the intersubband transitions and operating in the infrared and far infrared parts of the Spectrum exist already, notably the Quantum Well Infrared Photodetectors (QWIP) (for reviews see e.g. [2,3]).

Part of the QCL optimization amounts to limiting as much as possible the losses, notably for the THz emitting QCL's. Among other losses the Free Carrier Absorption (FCA) due to intrasubband as well as intersubband transitions needs to be accurately modelled. We shall show that there does not exist any Drude-like modeling of FCA in quasi 2D structures but that one should necessarily recourse to perturbative estimates or Green function techniques to account for these FCA losses. In contrast to Drude–like predictions we find that the FCA is very small in actual QCL devices, of the order of 10 cm^{-1} at room temperature where the LO phonon scattering dominates.

The intersubband scattering from the upper subband of the lasing transition is the dominant loss mechanism because it ruins the population inversion. It is usually evaluated at the Born approximation between the initial and final plane waves of the in-plane motion. However, before such an intersubband scattering event takes place, several intrasubband scattering events take place. In other words, it is more accurate to use initial and final states dressed by intrasubband scattering. These dressed states include bound or quasi bound states attached to the initial and final subbands. These bound states are necessarily absent from the regular Born approximation. Yet they are statistically important (compared to the extended states that lay at higher energies) and turn out to be more effective in the emptying of the upper subband.

Finally, we shall show that one may design a doping engineering of the intersubband transition where, by a suitable placement of the impurities, one may obtain one or two inter-subband absorption peaks at will [4].

REFERENCES

[1] J. Faist, F. Capasso, D.L. Sivco, A. Hutchinson, C. Sirtori and A.Y. Cho, *Quantum Cascade Laser,* Science **243**, 553 (1994).

[2] H.C. Liu and F. Capasso, *Intersubband Transitions in Quantum Wells: Physics and Device Applications I,* in *Semiconductors and Semimetals*, vol. 62, Academic Press, 2000.

[3]) H. C. Liu and F. Capasso, *Intersubband Transitions in Quantum Wells: Physics and Device Applications II,* in *Semiconductors and Semimetals*, vol. 66, Academic Press, 2000.

[4] C. Ndebeka-Bandou, A. Wacker, F. Carosella, R. Ferreira, and G. Bastard, *Dopant engineering of inter-subband linewidth and lineshape in multi-well heterostructures,* Appl. Phys. Express 6, 094101 (2013).

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