Magneto-transport measurements in Quantum Cascade Detectors

A. Gomez, N. Péré Laperne, L.A. De Vaulchier , C. Koeniguer,
A. Nedelcu, X. Marcadet, Y. Guldner, V. Berger

Abstract— **Magneto-transport experiments have been performed in Quantum Cascade Detectors. Theses experiments lead to a detailed contribution of different electronic transfers from subbands to subbands which participate in parallel to the global current in the structure. These different contributions are well described by a simple transport model based on the sum of diffusion events from a cascade to the next one through optical phonon mediated transitions. Magneto transport experiments shows the field of validity of this model and help the optimization of the structure.**

Index Terms— **photodetection, mid-infrared, quantum wells structures, magnetic field, transport modeling.**

Quantum cascade detectors (QCDs) have been proposed recently as a photovoltaic version of QWIPs. In a QCD structure, the optical transition brings an electron to a cascade of energy levels which transfers the charge from period to the next one. The key point in QCDs is the optimisation of the product between a high oscillator strength and a good electron extraction probability. Due to their photovoltaic behaviour, QCDs can work with higher doping levels than QWIPs and then work with higher quantum efficiencies, lower dark currents, longer integration times, at low voltage.

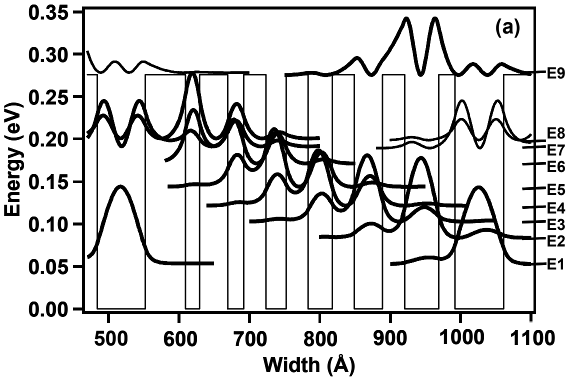

Fig. 1: Typical QCD structure. The optical transition takes electrons from the fundamental level E1 to the excited states E7 and E8. Electrons transfer from these levels to the next period (on the right of the figure) by successive relaxations in the cascade of levels.

An interesting difference between QCDs and QWIPs is the possibility of numerical modeling of the performances of QCDs, without any adjustable parameter. The transport in QCDs involves only 2D confined electronic states, and therefore all the electronic transitions from one subband to the other can be numerically extracted. In QWIPs, 3D states in the continuum result in complications such as capture and escape probabilities, which are usually not calculated but considered as adjustable parameters. As a result, the optimization of QWIPs has been obtained phenomenologically by scanning experimentally all the parameters. In the case of QCDs, it seems that the optimization of the structure can be performed completely numerically. This is the first time that such a route for

A. Gomez , C. Koeniguer and V. Berger are with the “Materiaux et Phenomenes Quantiques” laboratory of the University of Paris 7, batiment Condorcet, case courier 7021, 75205 Paris Cedex, France (corresponding author : e-mail: aurore.gomez@thalesgroup.com).
A. Nedelcu and X. Marcadet are with the Detection laboratory of “3-5 lab GIE”, Route Departementale 128, 91767 Palaiseau Cedex France
N. Péré Laperne, L.A. De Vaulchier and Y. Guldner are with the “Laboratoire Pierre Aigrain” of the Ecole normale supérieure, 24 Rue Lhomond, 75005 PARIS Cedex, FRANCE

optimization of an infrared detector can be followed. However, the numerical tool must first be validated seriously with experimental results.

The R0A parameter is a relevant figure of merit to characterize the dark current in QCDs. It can usually be described with an activation energy EA, corresponding to the energy of the transition responsible for electron transfer between two consecutive cascades. In the case where this transfer is dominated by a single electronic transition E1→Ej, a simple measure of R0A as a function of temperature leads to the identification of this transition . However, dark current in QCDs generally involves several diagonal transitions from one cascade to the next. In this case, the complexity of the process is hidden behind a single activation energy. For this reason, magneto transport measurements have been performed. They lead to the identification of the different transitions involved in the dark current as a function of temperature (Figure 2).

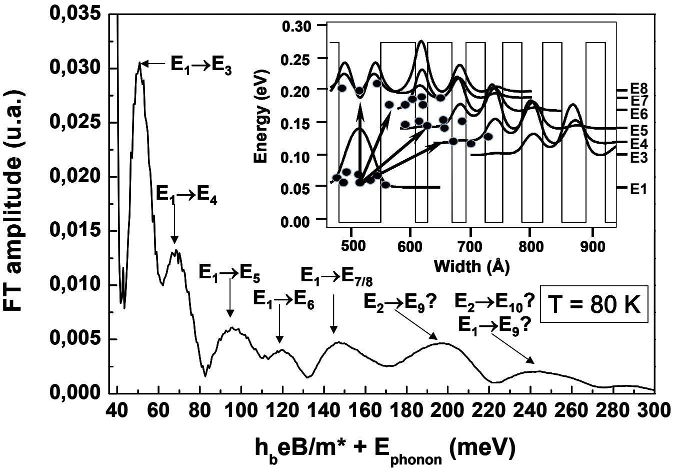

Fig. 2: Fourier Transform of the magneto-conductance component related to the transport in the QCD structure. This measurement leads to the identification of different electronic transitions involved in the transport. Other measurements at different temperatures show the modification of the electronic paths with temperature.

Magneto transport measurements will be shown, leading to the a full understanding of the detailed balance between the different electronic transitions involved in the transport. These experiments lead finally to a very satisfactory validation of our simulation of transport in QCDs at high temperature (from 80 K to 300 K) and to a better understanding of the transport mechanisms at lower temperatures.

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