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Abstract. In the present work, we performed photocurrent measurement on a quantum cascade detector structure under strong magnetic field applied parallel to the growth axis. The photocurrent shows strong oscillations as a function of B. We develop a model in order to describe current as a function of magnetic field. The excellent agreement with the experimental data supports the idea that an elastic scattering process plays a central role in the behavior of those structures. Thanks to zero magnetic field consideration, we establish that dominant process is impurities scattering process. These experiments lead to the key parameters to understand and optimize those structure further.

Keywords: Heterostructures;quantum cascade, mid infrared;magneto-transport
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At the cross road of quantum cascade laser (QCL) and quantum well infrared photodetector (QWIP), the quantum cascade detector (QCD) has been recently proposed[1]. From the band engineering point of view, these structures are directly designed as QCL without any applied bias voltage[1, 2]. The QCD structures are totaly passive systems and show a response only to photon excitation. In just a few years many QCDs have already been processed in the mid-infrared range[3] and in THz range[2]. The QCD structure is designed to generate an electronic displacement under illumination through a cascade of quantum levels without the need of an applied bias voltage.
In a semiconductor quantum wells structure, magnetic field applied along growth direction breaks the 2D in-plane continuum into discrete Landau levels. This experimental technique has been used in mid-infrared quantum cascade laser to show the influence of electron-LO phonon [4] and interface roughness[5] scattering .
We present in this paper photocurrent measurements under strong magnetic field applied along growth direction and a simple model of magneto-transport in a QCD. Through a comparison between experimental and calculation results, we put in evidence the scattering mechanism involved and limiting the response of QCDs.

The QCD under study is a $GaAs/Al_{0.34}Ga_{0.66}As$ heterostructure with a detection wavelength of $8\,\mu$m as described in ref. [6]. It consists of 40 identical periods of 7 coupled GaAs quantum wells (QWs). Figure 1 recalls the principle of the device.

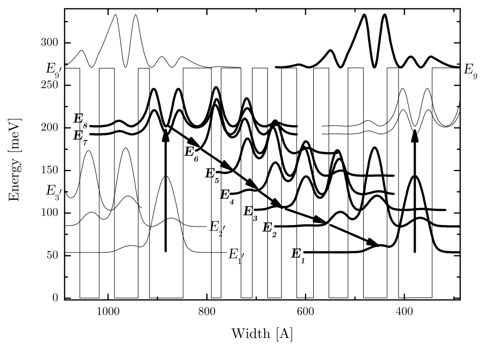

FIGURE 1. Conduction band diagram of one period of an $8\,\mu$m QCD showing the energy levels. Note that the ground state of the first QW belongs to the former period and is noted $E_{1'}$. The arrows illustrate the electronic path during a detection event. The layer sequence is as follows 67.8 / **56.5** / 19.8 / **39.6** / 22.6 / **31.1** / 28.3 / **31.1** / 33.9 / **31.1** / 39.6 / **31.1** / 45.2 / **50.8** (the barriers are represented in bold types). The n-doping of the large QW is $5 \times 10^{11}\,\mathrm{cm}^{-2}$.

QCDs are mounted inside an insert at the center of a superconducting coil where a magnetic field B up to 17 T can be applied parallel to the growth axis. Light is emitted by a globar source from a FTIR spectrometer and guided to the sample. The experiment consists in measuring the current under illumination (I_{80K}) without any applied voltage. We measured I_{80K} while the magnetic field is swept to its maximum value at $T = 80\,$K. Results

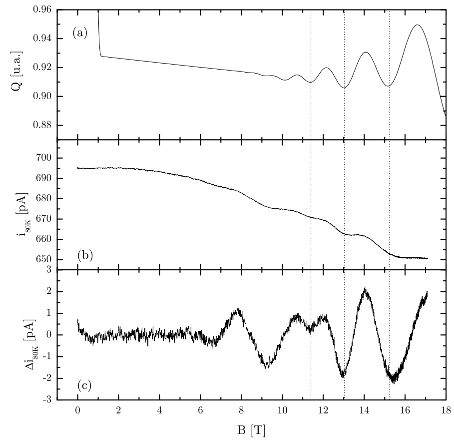

FIGURE 2. a) Quantum efficiency as a function of magnetic field calculated from electronic lifetimes. (b) Current under illumination as a function of magnetic field at 80K and 0V. (c) Current under illumination as a function of the magnetic field where the continuous contribution has been subtracted[6].

are illustrated in figure 2(b). The photocurrent shows oscillations as a function of the magnetic field, superposed on a general behavior corresponding approximately to a quadratic decrease. In order to remove this continuous component, we subtract the experimental data to a second order polynomial fit, the result is presented on figure 2(c). At 80 K, on figure 2(c), minima of current are located at $B = 11.3\,\mathrm{T}$, $13.0\,\mathrm{T}$, $15.2\,\mathrm{T}$. We propose a model of transport in one period by a rate equation approach. We assume that electrons are in the upper detector state (E_7) through absorption of a photon. Current as a function of lifetimes involved in this structure can be written:

$$\frac{J}{q} = \alpha N_{1'} \left(\frac{\tau_{7-1'}}{\tau_{7-1'} + \tau_{7-c}} \right) = \alpha N_{1'} Q \qquad (1)$$

α and $N_{1'}$ are respectively the absorption factor and population of level $1'$, these parameter are constant, the only figures which varies under magnetic field are the lifetimes. The lifetimes are directly deducted from calculation of scattering rates of the different elastic and inelastic mechanisms. As mentioned in reference [5], two mechanisms are dominant in these mid-infrared cascade structures, LO-phonon emission and interface roughness. In our structure, a third scattering mechanism become highly important, impurities scattering[7]. This mechanism is not negligible because impurities are located in the active well.

We present in table 1 the lifetimes of the different scattering processes at $B = 0$. We observe that impurities scattering is the much efficient process, indeed the wave function of level 7 is localized on the three first wells

TABLE 1. Rate of the different scattering processes for an electron on the 7 subband at $B = 0$.

Scattering mechanisms	$1/\tau_{7-1'}$	$1/\tau_{7-c}$
LO phonon	7.0×10^{11}	7.9×10^{11}
Interface roughness	2.0×10^{11}	2.5×10^{12}
Impurity scattering	3.5×10^{13}	4.5×10^{13}

of the structure, and the doped well exactly corresponds to the active region. For the interface roughness, we used a Gaussian autocorrelation of the roughness, with an average height $\Delta = 1.5$Å and a correlation length $\Lambda = 60$Å[5].

We do not have access to impurities scattering rate as a function of magnetic field. Therefore, we compare the oscillations on experimental data to calculation made versus magnetic field and involving another elastic process, namely interface roughness (Fig. 2(a)). We observe that minima are all well reproduced. So we can conclude that the dominant scattering process is an elastic one and thanks to zero magnetic field consideration, impurities scattering process is assumed to be the dominant one.

As a conclusion, we observe oscillations of current in a QCD under illumination as a function of magnetic field. These oscillations are due to the modulation of the scattering rate of an elastic process.

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