INTERSUBBAND LIFETIME MAGNETOPHONON OSCILLATIONS IN MIR GAAS QUANTUM CASCADE LASERS

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Introduction

Recently, it has been demonstrated that a strong perpendicular magnetic field causes strong oscillations of intersubband laser emission in the mid-infrared (MIR) quantum cascade lasers (QCLs) [1]. These oscillations have been explained as signatures of intersubband magnetophonon effect arising from resonant electron-optical phonon relaxation. In this report we present the magnetic field dependence of intersubband lifetime derived from the experiment and compare it to the calculated electron-LO phonon scattering rates.

Experimental

We have measured emission intensity as a function of current bias and magnetic field in MIR GaAs/AlGaAs QCLs. Since the QCL structures operate under high current bias up to a few amperes, we have developed an experimental set-up that allows for high current, fast pulsed measurements. The system has the capability to deliver current pulses with controllable amplitudes (up to 3 A), duration (>600ns), duty cycle, and edge times. The measurements were done at 5K and 80K in the I//B geometry (B ⊥ 2D planes).

Results and Discussion

Laser emission is strongly affected by the magnetic field and shows strong oscillations in intensity P(B), threshold current Ith(B) and in differential quantum efficiency dP/dI (Fig.1). These oscillations are due to a modulation of the lifetime of the upper state of the laser transition \( \tau_3 \), which is controlled by electron-optical phonon scattering. Considering an idealized 3-level model, we derived the intersubband scattering rate dependence on a magnetic field \( 1/\tau_3(B) \) from the field dependence of QCL’s threshold current (Fig.2a) [2]. We have to note that within the same approximation, dP/dI does not depend directly on \( \tau_3 \), and therefore it should not oscillate with the magnetic field as observed experimentally. Instead, it may arise from the magnetic field dependence of the injection rate assumed so far to be constant with magnetic field.

Calculation of electron-LO phonon scattering rates have been done following the model described in Ref.3. The calculated scattering rates are shown in Fig.2b. Peak positions and widths are in good agreement with the experimental results at high fields. The differences in the region between 15T and 20T are due to elastic relaxation processes (level 3 resonant with an excited Landau level from lower subbands), made possible by ionized impurities, electron-electron scattering or acoustic phonon interaction, which are not included yet in our model.

References