ELECTRONIC SCATTERING MECHANISM SPECTROSCOPY IN TWO-LEVEL QUANTUM CASCADE STRUCTURES SUBJECTED TO HIGH MAGNETIC FIELDS

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Introduction

Quantum Cascade Lasers (QCL) [1] are unipolar inter subband devices emitting in middle infrared and far infrared range of energy. Different material systems such as GaInAs/AlInAs, GaAs/AlGaAs or InAs/AlSb are used to produce laser emission from 4 µm up to 160 µm. In these devices, the population inversion condition can be achieved thanks to the resonant emission of optical phonons leading to an efficient evacuation of carriers out of the fundamental state of the radiative transition. As was demonstrated with QCLs [2], magnetic field offers a unique tool to study electron scattering mechanisms in quantum cascade structures. In traditional QCLs, the phonon energy is an intrinsic frequency of the system as it is used in the design of the structure for carrier evacuation. We have designed two-level quantum cascade structures in order to study scattering mechanisms in a model system. The aim of this project is to compare these mechanisms and their relative importance in active regions elaborated in different material systems.

Experimental Details

Recent studies [3] made on QCLs showed that electrical characteristics of QCLs in magnetic fields show the same behavior as the optical characteristics. We have then measured in pulsed operation at a fixed voltage the evolution of the current injected as a function of the magnetic field for three two-level structures mesas elaborated in different material systems, GaInAs/AlInAs, GaAs/AlGaAs and InAs/AlSb. The mesas have a diameter of 100 µm. The magnetic field dependence has been measured at different fixed voltages in order to explore the different alignment regimes (below and above the voltage knee). Measurements have been performed in pulsed mode operation (pulses of 40 µs at 2.5 KHz) from 0 to 32.7 T at a temperature of 7 K.

We have also measured the evolution of the luminescence as a function of the magnetic field. This measurement has been possible only on the InAs/AlSb structure up to now because of its high radiative efficiency. We have demonstrated that these measurements are also possible on the other material systems, but we did not measure the magnetic field dependence.

Results and Discussion

At this time, only preliminary analysis of the electrical and optical characteristics has been performed. We observe on the evolution of the current two main features on all samples: a strong decrease of exponential type of the injected current with increasing magnetic fields, and superimposed oscillations of the current periodic in 1/B revealing the excited state lifetime. These oscillations are induced by the elastic and inelastic scattering of electrons out of the excited state of the radiative transition.

The measure of the luminescence of the InAs/AlSb structure gives a direct measure of the quantum efficiency of the system, which also shows pronounced oscillations. Results are clearer with this measure and we are able to extract the elastic scattering contribution and the inelastic scattering contribution.

This experiment shows that two-level structures provide a well adapted system to study electron scattering mechanisms in quantum cascade structures. We now know that it is possible to measure the luminescence intensity in high magnetic fields and we intend to perform this measurement on GaAs/AlGaAs and GaInAs/AlInAs systems.

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References

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