ELECTRON SCATTERING SPECTROSCOPY BY HIGH MAGNETIC FIELDS IN GaAs/AlGaAs AND GaInAs/AlInAs MID-INFRARED QUANTUM CASCADE LASERS

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Introduction

Applying strong magnetic fields perpendicular to the 2DEG in semiconductor quantum wells breaks the 2-D in-plane continuum into discrete Landau Levels. Subsequently, the magnetic field strongly modulates and modifies the lifetime of the electrons in their excited states. This general property of heterostructures has been recently exploited in mid-infrared quantum cascade lasers (QCLs), where Landau quantization was used in order to control electron-LO phonon scattering [1,2]. The aim of this work is to use magnetic fields as a spectroscopic tool to study the scattering mechanisms that take place in mid infrared GaAs/AlGaAs and GaInAs/AlInAs QCLs.

Experimental

The details of QCL structures are described in reference 3. The measurements were performed in the temperature range of 5-80 K with the magnetic field applied perpendicular to the 2D planes of quantum wells (QWs). The QCL structures were mounted in the I // B geometry in the center of DC magnets capable of max fields of 18 T (SCM), 25-33 T (resistive magnets) and the 45 T (hybrid magnet). Electric current though the sample has been driven in pulsed mode with 1-5% duty cycle and 0.2-2 μs pulse width. Emitted IR radiation was guided by light pipes towards an external HgCdTe detector. The spectral measurements were performed with a Bruker 66v Fourier-transform infrared spectrometer.

Results and Discussion

We observed pronounced oscillations of magnetoresistance, laser emission intensity, and laser threshold current. These oscillations are caused by the magnetic field modulation of the lifetime through resonant inelastic and elastic scatterings. By comparing experimental and numerical results, we have found that in a GaAs/AlGaAs system, the dominant scatterings are LO phonon and interface roughness, where as for GaInAs/AlInAs structures, it is determined by LO phonons, alloy disorder, and interface roughness. Finally, we have deduced numerical values of scattering rates and typical parameters of the interface roughness correlation function.

Conclusions

We have shown that the magnetic field is an efficient spectroscopic tool to ascertain the nature and magnitude of the scattering mechanisms in the active region of a QCL. The results for GaAs/AlGaAs QCLs will be published under ref. 3, and the GaInAs/AlInAs QCL results are in the process of being written up for publication.

Acknowledgements

We gratefully acknowledge support from NHMFL In House Research Program (project 5053).

References