OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG NAT FAKULTÄT FÜR NATURWISSENSCHAFTEN

Physikalisches Kolloquium

Dienstag, 27. November 2018, 16:30 h
Gebäude 16, Raum 215

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Electron-phonon interaction in low dimensional structures: from Fermi golden rule to strong coupling

Low dimensional structures are obtained by reducing the size of the continuum for the electron free motion through etching or epitaxy. They have met considerable successes in applications (Quantum Well (QW) lasers, Quantum Dot (QD) lasers, High Electron Mobility transistors, Quantum Cascade lasers,…). The behavior of these devices crucially depends on how efficiently the electrons can release their excess energy. This is achieved by interacting with the phonons. When available (III-V, II-VI polar materials) the emission of Longitudinal Optical (LO) phonons by the Fröhlich coupling is by far the most efficient mechanism for energy relaxation. Using the Fermi golden rule, it is possible to compute the energy loss rate of the carriers in QW structures associated with phonons emission and absorption. The modeling is in quantitative agreement with experiments.

The very same model applied to QD's with nanometer size necessarily leads to the notion of phonon bottleneck, i.e. to the impossibility of energy relaxation in zero dimensional structures, essentially because their low energy electronic spectrum is discrete and the LO phonons are quasi monochromatic. However, an inhibited relaxation was sometimes observed, sometimes not, depending on the QD parameters and/or materials.

The puzzle was reconstructed by observing the existence of pronounced anti-crossings in the magneto-absorption spectra associated with S-P transitions of QD ensembles. A quantitative modeling of the S-P transition energies based on a strong coupling between electrons and LO phonons (i.e. the formation of mixed elementary excitation between electrons and LO phonons, the polarons) was achieved. It rules out the use of Fermi golden rule for zero dimensional structure. This feature is analogous to the strong coupling between atoms and photons in cavities.

Yet, the polarons relax their energy because of the natural instability of LO phonons due to the vibration anharmonicity. I will discuss the outcome of this unconventional relaxation process in semiconductors in the specific case of QD's and show that it allows an excellent description of pump and probe experiments undertaken by the Sheffield group on InAs QD's with different sizes.

This work was done in close collaboration with Drs R. Ferreira and Y. Guldner at ENS.

Alle Interessierten sind herzlich eingeladen!

gez. Prof. Dr. Claus-Dieter Ohl