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COND-2 TALK 14:15-14:30 TUESDAY, SEP 11 HS P2

Quantum Cascade Laser and Detector Material Systems

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Quantum cascade lasers (QCL) and detectors (QCD) enable spectroscopy in the MIR and THz finger print regions, spanning 3 – 300 μm. The material systems used and the band structure engineering they enable determine the properties of intersubband devices. The cubic III-V material systems have been dominant, due to the availability of high quality substrates (GaAs, InP, InAs, GaSb), lattice-matched or strain-compensated barriers, various conduction band offsets (CBO), low electron effective mass m_e^*, and available wave guiding. Large CBOs and a high barrier effective mass m_e^* are helpful for creating short wavelength QCLs and QCDs. However, to improve long wavelength emission, up to the reststrahlen band and above it in the THz range, the large CBO and m_e^* leads to 1-2 monolayer (ML) thick barriers that are challenging to grow uniformly and reproducibly. InAs and InGaAs are the lowest m_e^* well materials, so lattice-match III-AsSb have been developed to tune the CBO and m_e^*.

Symmetric THz QCLs have proven to be an excellent method to study material and interface quality, as well as dopant migration. Interface quality and asymmetry can be compared by the changes in the L-I-V curves for the two bias directions,. This allows the identification of higher quality normal InGaAs-to-InAlAs and inverted InAlAs-to-InGaAs interfaces. For InAs/AlAsSb THz QCLs, the AlAsSb barriers are 1-2 ML and lead to more scattering, while 4 ML barriers are suitable for MIR QCDs. In the quest to improve III-AsSb materials, like GaAsSb and AlAsSb, the As-for-Sb exchange becomes a significant factor in growth crystal quality, alloy composition, and lattice matching.

We will present the growth and progress made in materials for MIR and THz devices, including which material system can be used reliably to reach 190 K pulse operations for THz QCLs.

COND-3 TALK 14:30-14:45 TUESDAY, SEP 11 HS P2

Surface emitting ring interband cascade lasers

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Interband cascade lasers (ICLs) [1,2] combine the concept of quantum cascade lasers (QCLs) and conventional photodiodes, because they rely on the voltage-efficient in-series connection of multiple active regions as in QCLs as well as the long upper-level recombination lifetimes of photodiodes. The distinctive low power consumption of ICLs makes them suitable candidates for compact mid-IR devices for process control, medical applications and spectroscopy [3].

This work presents special ICL-devices for spectroscopic applications. As a first proof of principle we present ICLs fabricated into ring-shaped cavities [4]. The light is outcoupled in vertical direction through the GaSb substrate using second order distributed feedback (DFB) gratings. The first demonstrated devices with 400 μm outer diameter and a waveguide width of 10 μm show light emission at a wavelength of ~ 3.7 μm. A pulsed threshold current density < 1 kA/cm² is measured at 20°C.

We use our devices for trace gas sensing by the principle of $2f$-wavelength modulation Fabry-Pérot photothermal interferometry and show first results with ICLs in contrast to previous measurements using QCLs [5].

Additionally, we also investigate the suitability of related QCL-concepts to implement them to our ring ICLs (e.g. 2D DFB QCL arrays [6]).

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[5] J. P. Waclawek, V. C. Bauer, H. Moser, and B. Lendl, $2f$-wavelength modulation Fabry-Perot photothermal interferometry, *Opt. Express* **24**, 28958-28967 (2016).

[6] E. Mujagić, C. Schwarzer, Y. Yao, J. Chen, C. Gmachl, and G. Strasser, Two-dimensional broadband distributed-feedback quantum cascade laser arrays, *Appl. Phys. Lett.* **98**, 141101 (2011).

COND-4 TALK 14:45-15:00 TUESDAY, SEP 11 HS P2

Diagrammatic Monte Carlo study of Fröhlich polaron dispersion in two and three dimensions

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The Diagrammatic Monte Carlo (DMC) is a powerful method which has proven to work in many applications for many different systems. It makes use of diagrammatic expansions of Green's functions and a Metropolis sampling algorithm to perform a random walk in the space of all Feynman diagrams.

For this paper, we have implemented a DMC code based on the approach by Mishchenko et al.[1] and applied it to the solution of the large polaron Fröhlich Hamiltonian in three (3D) and two dimensions (2D). We benchmarked our code with existing DMC results for the 3D case to verify its correctness and then computed polaron ground state energies, effective polaron masses and polaron dispersion curves in 2D and 3D. The results are compared to analytically known limits and to other numerical results from the literature.

Our data confirm that the effect of electron-phonon coupling is enhanced when going from 3D to 2D systems, and this is reflected in all computed physical quantities. The calculated ground state energies from our DMC code are in very good agreement with Feynman's path integral approach