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BOOK OF ABSTRACTS

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Symmetric THz Quantum Cascade Lasers as a Tool for Growth Optimization

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Quantum cascade lasers (QCLs) are an established class of light sources for the mid-infrared and THz wavelength ranges. While continuous-wave operation at room temperature is standard for MIR devices, the integration of THz QCLs into optical systems is hindered by their requirement of cryogenic technology. Presently, lasing was shown up to 200 K. In addition to GaAs/AlGaAs, also InGaAs/GaAsSb heterostructures were demonstrated to be viable alternatives for THz QCLs [1-2].

In this work, we present symmetric THz QCL active regions for the GaAs/AlGaAs and InGaAs/GaAsSb material systems, based on a 3-well phonon depletion scheme [3]. All QCLs discussed here were grown by solid-source molecular beam epitaxy, where in the case of InGaAs/GaAsSb heterostructures switching between the materials was done by shutter operations only. Samples were processed into double-metal ridge waveguides with identical top and bottom Ti/Au contacts. These structures allow to measure electrical transport and lasing for both bias polarities, which can be used to study the elastic scattering mechanisms. The fact that these are nominally symmetric structures allows to trace deviations for opposite bias back to non-ideal behavior during growth. In the case of InGaAs/GaAsSb structures, transmission electron microscopy (TEM) images revealed two different interface qualities. The transition from the mixed group V compound to the pure arsenide leads to an increase in the interface roughness. This can also be corroborated with electrical transport measurements, as the designed alignment is reached for lower current densities, when the wavefunction of the upper laser level is pushed towards the sharp interface. Opposite bias polarity results in increased scattering due to the rougher interface and therefore requires higher current densities. Consistently also the lasing threshold is lower for electron transport along the growth direction. On the other hand, GaAs/AlGaAs devices show a lower threshold for electron transport counter the growth direction, which we attribute to dopant migration during growth. By shifting the doping profile against the growth direction, we were able to achieve equal thresholds for both polarities. However, also in this case, the optical output power and maximum operation direction are higher for electrons flowing against the growth direction, which again can be explained with asymmetric interfaces, when switching from GaAs to AlGaAs and back.

We therefore state that symmetric THz QCL active regions are a powerful tool to study scattering mechanisms due to growth related imperfections. Since a large number of interfaces and scattered electrons are probed, this technique is a valuable complement to TEM images and allows to optimize both, the epitaxial growth and the quantum mechanical design of these devices.

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