Terahertz-Quantum Cascade Emitters

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The need of electrically driven compact sources of coherent radiation in the frequency regime between 1 and 10 THz has stimulated the development of a terahertz (or far-infrared) quantum cascade (QC) laser [1-3]. A simple scaling of successful band structure concepts of mid-infrared QC-lasers [4] is impracticable because resonant emission of longitudinal optical (LO) phonons (in GaAs at 8.7 THz, 36 meV) cannot be utilized likewise, and fast non-radiative intersubband relaxation counteracts population inversion [1].

We demonstrate experimentally two ways to reduce the intersubband relaxation rate significantly. First, the rate is reduced in a magnetic field applied perpendicular to the growth direction [5]. This effect manifests itself in an enhancement of the electroluminescence efficiency and in a reduction of the current. The electroluminescence intensity and the current show characteristic magneto-oscillations stemming from Landau-intersubband resonances. The periodicity of the oscillations allows to deduce the energy of the intersubband transition. The amplitude of the oscillations is a measure for the fraction of the current undergoing the transition designed for luminescence, and thus for the injection efficiency.

Secondly, the relaxation rate decreases as initial and final suband of the laser transition are spatially separated by a barrier. Two band structure schemes (emission at 18 meV, 4.4 THz) have been compared, one based on an intrawell transition, the other based on an interwell transition across a barrier [6]. The interwell emission peak exhibits a Stark-shift of 6 meV. Both samples have roughly the same efficiency. This means that the total relaxation rate is reduced by the same amount as the radiative transition rate when the initial and final subbands are spatially separated.

An improvement of the injection efficiency of the chirped superlattice energy filters is achieved by incorporating thin AlAs barriers instead of $Al_{0.15}Ga_{0.85}As$ barriers. The higher barriers suppress the fraction of the current not passing through the laser transition. This becomes obvious from a smaller overall current density, from a stronger oscillatory component in the current vs. magnetic field characteristics, and from a higher electroluminescence efficiency.

References

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