上位準位へのリーク電流低減による THz-QCLs の高出力化

Increased output power of THz QCLs by reducing leakage current via upper levels

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THz quantum cascade lasers (QCLs) are promising high output power semiconductor THz sources to over Watt order peak power with narrow bandwidth. Here we theoretically analyze THz QCLs based on non-equilibrium Green's function (NEGF) method, indicate an extra carrier leakage channel from the upper lasing levels to the first excited state in the double emission wells in the next down-flow period, which can be directly visible in the energy-position resolved current mapping. This leakage channel is due to unintentional alignment of the two states and exists even at 10 K, which is distinct from the thermally activated leakage channels [1]. The energy level of the excited state can be tuned by optimizing the thickness of corresponding barriers/wells, and consequently the unintentional coupling can be reduced. As a result, this leakage current has been clearly suppressed. Following such an optimization procedure, high output power from GaAs THz QCLs based on resonant tunneling phonon depopulation scheme has been obtained. The optimized THz QCLs devices deliver 350 mW peak power at 10 K but only with a size less than ¼ of that for the devices with the highest reported output powers. This extra leakage channel should be carefully considered and be avoided during designing in order to exploit the full potential of THz QCLs.

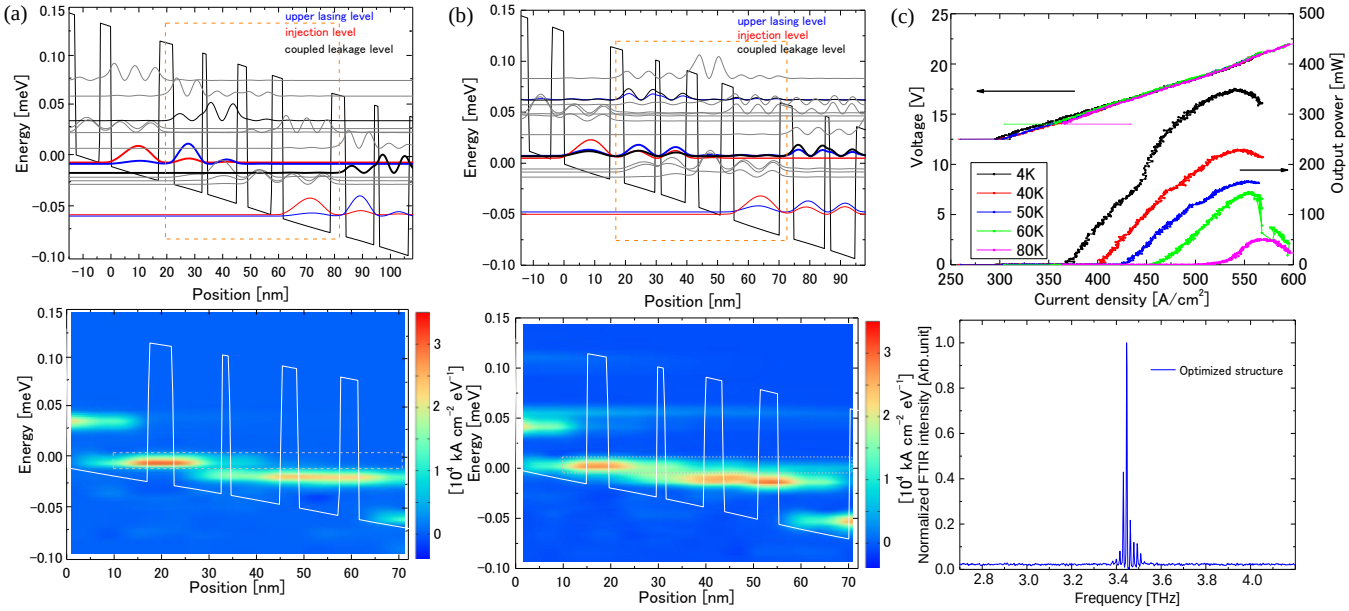

Figure 1. Band diagrams and current density mappings operating at 10K of GaAs/AlGaAs THz-QCLs for (b) the design for reducing current leakage to upper energy levels and (c) usual design, analyzed using NEGF method. (c) Measured Lasing spectrum of optimized structure, temperature dependent current density - voltage characteristics, and current density - light output characteristics of optimized THz QCLs.

[1] T.-T. Lin, H. Hirayama. Phys. Status Solidi A (2017), 1700424

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