Intersubband quantum-box lasers: Progress and potential as uncooled mid-infrared sources

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Semiconductor lasers whose active region is composed of a 2D array of intersubband quantum boxes (IQBs) hold the promise [1] to be significantly more efficient than many-stage (*i.e.*, 30-40) intersubband lasers, the so-called quantum-cascade lasers (QCLs). That is a direct consequence of the fact that the electron-relaxation times in deep, unipolar QBs are at least a factor of 30 times larger than in quantum wells, as experimentally confirmed by several groups [2].

We have reported [3] on the suppression of carrier leakage in 4.8 μm QC lasers by using a new concept: deep quantum wells and tall barriers in the devices' active regions. As a result the threshold-current density and slope efficiency vary with temperature *half as fast* as for conventional QCLs. Such deep-well structures are crucial for the achieving the tight carrier confinement needed in the QBs of the envisioned IQB lasers.

Another significant achievement was obtaining, for the first time, electroluminescence (EL) from quantum-box structures fabricated by etch and regrowth. That was made possible by the development a surface passivation technique that eliminates Fermi-level pinning at the dry-etched/regrown sidewalls of the nanopoles used in the fabrication of IQB devices, and thus depletion of the IQBs is avoided. The EL spectral widths of IQB structures are similar to those obtained from single-stage devices, thus confirming theory [1]; in that, for IQBs made by etch and regrowth, the emission spectra are not sensitive to variations in the IQB lateral dimensions.

IQB lasers of 2D arrays of 1-4 QB ministacks hold the potential to achieve wallplug efficiencies as high as 50% at room temperature. At low output power (~20 mW) the dissipated heat will be ~50 mW, thus allowing mid-IR *uncooled* operation. For high, coherent power (~0.8 W) devices, the power will be scaled laterally by using active photonic crystal structures, similar to the ones successfully used [4] in the near-IR. Then the dissipated heat will be ~1 W, which would also allow for uncooled device operation. The realization of uncooled mid-IR sources will make possible hand-held, real-time sensors for non-invasive medical diagnostics (*e.g.*, breath analysis), practical sensing of chemical agents and explosives, and remote sensing from air vehicles.

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