High performance THz Quantum Cascade Lasers

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Quantum Cascade Lasers (QCLs) are very successful quantum devices which cover a broad spectral range from the infrared to the THz. However, their operation is still limited in terms of operating temperature, output power and beam properties. Therefore, we investigate new material systems, active region and cavity designs.

We use InGaAs/GaAsSb due to the lower effective mass and lower conduction band offset. Record operating temperatures are achieved despite the large interface roughness asymmetries in this material. New doping profiles are introduced which are motivated by the study of symmetric active regions. This has led to a significant improvement of the operating temperature of InGaAs/InAlAs structures. The improved understanding of coherent and incoherent transport in complex heterostructures allowed the realization of high operating temperature GaAs/AlGasAs QCLs suitable for thermo-electric cooling.

Another strategy to improve the performance is to increase the number of cascades in the active region. However, due to the epitaxial growth the maximum active region thickness is limited to around 10–15 μm. To circumvent this growth problem we developed a direct wafer-bonding technique to increase the thickness of the active region by stacking the same active region. With these devices we reach record output power levels of almost 1 Watt and a significantly improved far field. This performance allows real time THz imaging using micro bolometer cameras.

The unique properties of QCLs allow the fabrication of photonic crystals, micro pillar arrays as well as of micro-cavities. Usually, these devices are characterized by narrow spectral windows and cannot take advantage of the larger spectral gain bandwidth offered by Quantum Cascade structures. An unconventional concept which overcomes this limitation is a random laser. We have realized a Quantum Cascade random laser which produces coherent broadband THz radiation as well as an almost diffraction-limited far-field surface emission profile. Our random lasers do not require any fine tuning and thus constitute a promising example of practical device applications.

The excellent properties of THz QCLs and evanescent coupling establish an attractive basis for the realization of on-chip circuits. On-chip generation and detection of terahertz radiation becomes available since intersubband transitions can be used for emission or detection and modulation. We will show a few coupled cavity systems e.g. as emitter – detector system, bi-stable switch or ultrafast modulator.

REFERENCES

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