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# A customized THz quantum-cascade laser as the local oscillator for a heterodyne receiver at 4.745 THz


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Quantum-cascade lasers [1] (QCLs) for the terahertz (THz) spectral region [2] are promising light sources for several spectroscopic applications and THz imaging. For practical use, however, the challenge consists in the simultaneous fulfillment of specifications for an entire set of operating properties such as lasing frequency, optical output power, and beam profile within a single device. At the same time, the lasers have to comply with the range of operating temperatures and pumping powers defined by the specific application.

We discuss the design and optimization of customized THz QCLs. As an example, we report on the development of a local oscillator used in a heterodyne receiver for the investigation of interstellar atomic oxygen. In this case, the source is required to emit in continuous-wave (cw) mode with a tuning range of about 5 GHz either just below or above 4.745 THz. For single-mode operation with the required tuning range, we fabricated distributed-feedback (DFB) lasers combining a single-plasmon QCL with a lateral first-order grating. Tuning is achieved by adjusting the effective refractive index of the resonator through the temperature inside the device by varying the driving current. Therefore, the QCL is required exhibit a sufficiently large wall-plug efficiency over a rather wide range of current densities, but with a negligible spectral shift of the gain maximum.

The design procedure includes the optimization of an appropriate design type using a self-consistent model based on classical rate equations. For this optimization, also reabsorption and negative differential conductivity has to be regarded. The wafers were grown by molecular-beam epitaxy. In order to improve the homogeneity of the about 10 $\mu$m thick active region, the growth rates were controlled using optical monitoring. Lasers with emission close to the target frequency can be operated in cw mode at low temperatures with more than 10 mW output powers and above 60 K with about 1 mW. The DFB laser ridges were fabricated by dry etching. For a DFB laser which shows emission covering precisely the required frequency range, we achieved an output power of about 0.5 mW for operation between 42 and 47 K in a mechanical (liquid-coolant-free) cooler. Under these conditions, the beam profile is almost circular [3].

The results demonstrate the potential of THz QCLs as well as the applicability of the rate-equation model. At the same time, we observed differences between nominally identical samples, which show the complexity of the QCL structures and reveal the remaining challenge for the growth and fabrication in order to achieve the highest possible output power at the target emission frequency in a single device.


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