Long wavelength Terahertz Quantum Cascade Lasers emitting down to 1.2 THz

Christoph Walther*, Milan Fischer, Giacomo Scalari, Jérôme Faist
Institute of Physics, University of Neuchâtel, CH-Neuchâtel, Switzerland
*Email: christoph.walther@unine.ch

***Abstract*—We report operation of terahertz quantum cascade lasers at frequencies from 2.0 THz down to 1.2 THz by using a bound-to-continuum based lasing scheme which combines high injection efficiency and low intersubband absorption.**

Compact, coherent and tunable sources of terahertz (THz) radiation are highly desirable for a number of applications including imaging [1], spectroscopy [2] and local oscillators [3].

The recent demonstration [4] and rapid development [5], [6] of THz quantum cascade lasers is tracing a new way for the generation of intense THz frequencies with semiconductor devices. THz quantum cascade lasers have been demonstrated from 4.8 THz down to 1.6 THz [7]. By applying intense magnetic fields lasing has been demonstrated down to 1.39 THz [8]. From a technological point of view it would be desirable to extend the operation range of THz quantum-cascade lasers down to 1 THz without requiring intense magnetic fields.

Quantum cascade lasers in the so far underdeveloped frequency range from 1 to 2 THz would be especially interesting for high resolution heterodyne spectroscopy [3] of molecular rotational lines.

The main challenges for designing THz quantum-cascade lasers below 2 THz are represented by the achievement of high injection efficiency of electrons from the injector in the upper state with minimization of the current flow prior to alignment and the minimization of the intersubband absorption in the injector at the photon frequency.

Here we present results on long wavelength quantum-cascade lasers in the frequency range of 1.2 to 2.0 THz. The lasing scheme is based on a bound-to-continuum transition with an energy gap [7]. The role of the energy gap is to increase the energy separation between the miniband and the injector states which results in low intersubband absorption at the photon energy and high injection efficiency of electrons in the upper state.

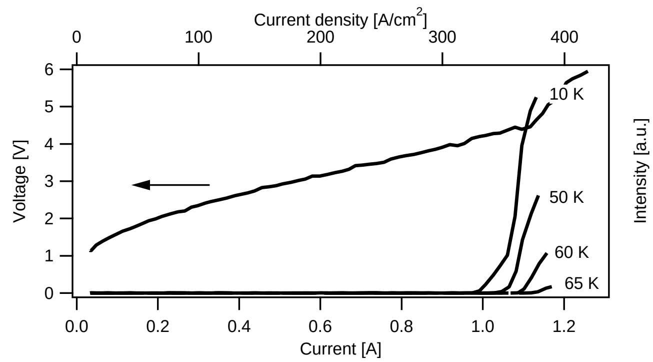

Fig. 1. Laser emission as a function of injected current for different temperatures and current-voltage characteristic at 10 K in the pulsed mode for a the sample which is emitting down to 1.21 THz.

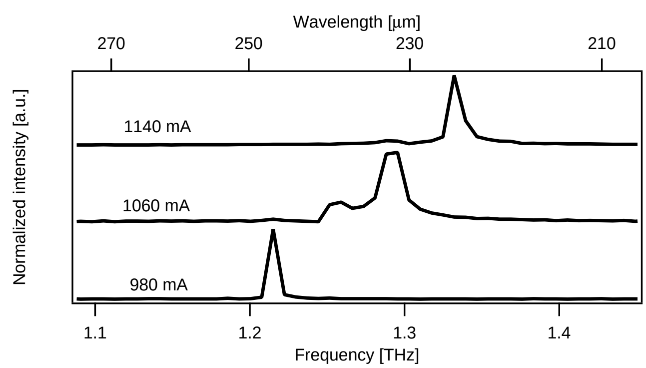

Fig. 2. Spectra at different currents at 10 K in the pulsed mode. The center of mass of the lasing emission shifts with increasing current from 1.21 THz to 1.33 THz.

We realized a series of lasers based on the bound-to-continuum design to cover the frequency range from 2.0 THz ($h\nu = 8.3$ meV, $\lambda = 150$ μm) down to 1.2 THz ($h\nu = 5$ meV, $\lambda = 250$ μm). Our lasers show a strong Stark-shift with the voltage due to the diagonal nature of the bound-to-continuum transition. Figure 1 shows the electrical and temperature characteristics of the laser with emission between 1.21 THz and 1.33 THz. The spectra at different currents are shown in Figure 2.

References

[1] D. Mittleman, R. Jacobsen, and M. Nuss, IEEE J. Quantum Electron. **2**, 679 (1996).
[2] P. Siegel, IEEE Trans. Microwave Theory Tech. **50**, 910 (2002).

[3] J. Gao, J. Hovenier, Z. Yang, J. Baselmans, A. Baryshev, M. Hajenius, T. Klapwijk, A. Adam, T. Klaassen, B. Williams, et al., Appl. Phys. Lett. **86**, 244104 (2005).
[4] R. Köhler, A. Tredicucci, F. Beltram, H. Beere, E. Linfield, A. Davies, D. Ritchie, R. Iotti, and F. Rossi, Nature **417**, 156 (2002).
[5] B. Williams, S. Kumar, Q. Hu, and J. Reno, Optics Express **13**, 3331 (2005).
[6] B. Williams, S. Kumar, Q. Hu, and J. Reno, IEE Elect. Lett. **42**, 89 (2006).
[7] C. Walther, G. Scalari, J. Faist, H. Beere, and D. Ritchie, Appl. Phys. Lett. **89**, 231121 (2006).
[8] G. Scalari, C. Walther, J. Faist, H. Beere, and D. Ritchie, Appl. Phys. Lett. **88**, 141102 (2006).