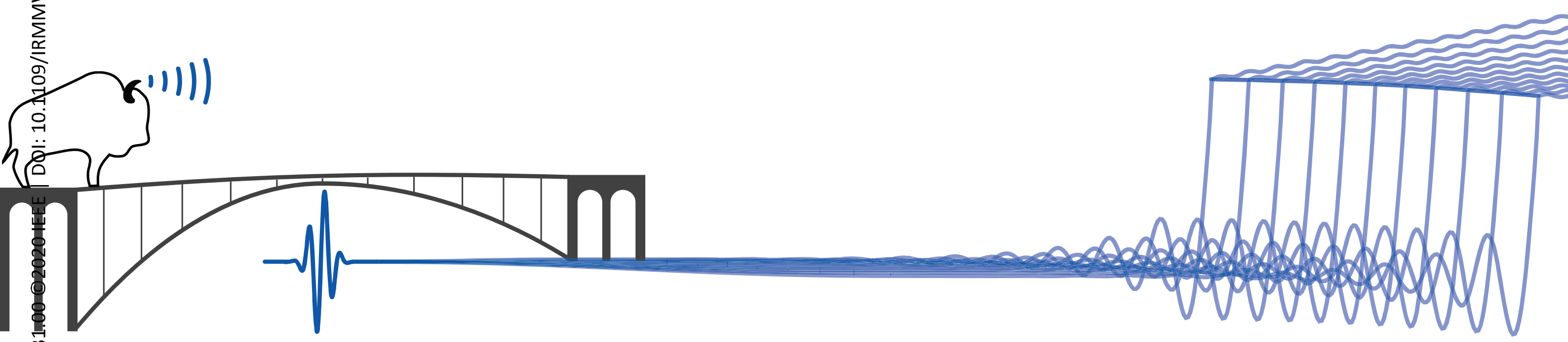
2020 45th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz)



November 8–13, 2020

A virtual event hosted from Buffalo, New York, USA

www.irmmw-thz2020.org

Part number: CFP20IMM-ART | ISBN: 978-1-7281-6620-9 | ISSN: 2162-2035

Terahertz intersubband electroluminescence from ZnO quantum cascade structures

B. Meng[1], B. Hinkov[2], H. Hoang[2], M. Hugues[3], N. Le Biavan[3], D. Stark[1], G. Strasser[2], J.-M. Chauveau[3], and Jérôme Faist[1]

[1]Institute for Quantum Electronics, ETH Zurich, Zurich 8093, Switzerland

[2]TU-Wien, Nanocenter Campus-Gußhaus, Gußhausstraße 25, Gebaude-CH, A-1040 Vienna, Austria

[3]Université Côte d'Azur, CNRS, CRHEA, 06560 Valbonne, France

***Abstract*—Terahertz intersubbband electrolulminescence from ZnO quantum cascade structures, based on four quantum well per period, is presented. The whole cascade structure was grown on the m-plane ZnO substrate. An electroluminescence peak with a linewidth of ~ 20 meV is observed at 8.5 THz, in consistent with the numerical simulation by a density matrix model.**

I. INTRODUCTION

THE first terahertz (THz) quantum cascade laser (QCL) was demonstrated in 2002 and operated up to 50 K [1]. Over the years, continuous improvement of the maximum operation temperature has been realized with a T_{max} of 210 K recently reported through nonequilibrium Green's function (NEGF) optimization [2]. Besides the optimization of the GaAs-based material system, new material systems with large LO-phonon energy are postulated to be promising candidates for improved temperature performance of THz QCLs, i.e. ZnO. Compared with GaAs material system, ZnO features a much larger LO-phonon energy of 72 meV, which significantly suppresses the scattering of thermally activated LO-phonon emission at high temperature, thus improving the high temperature performance of the THz QCLs. On the other hand, the high energy of *reststrahlen* band of ZnO enables light emission at high frequency range, i. e. 8-9 THz, which in the GaAs system is limited by the strong *reststrahlen* band absorption [3,4].

II. RESULTS

The layer sequence of the cascade structures studies in this work grown by the molecular beam epitaxy (MBE) on the m-plane substrate is shown in Fig. 1(a). The active region layers was repeated by 100 times to increase the model gain, with a doping level of 3e18 cm^{-3} and total thickness of around 2.5 µm. The Mg content is kept at 12% over the whole structure, leading to a bandoff of ~200 meV close to that of GaAs-based QCLs. The active region was designed using a four-well architecture consisting of a bound-to-continuum diagonal active region design, which has been shown to be suitable for different material systems and growth techniques due to its tolerance of the design to small variations in the layer thickness [5]. The corresponding subband energies and the wavefunctions of the active region, calculated under the applied electric field of 50 kV/cm using our self-consistent Schrödinger–Poisson is shown in Fig. 1(b).

In this study, chirped grating structures were etched down to the 470 nm buried doped layer [6], with the period varying from 15 µm to 31 µm, as shown in the inset of Fig 1(c). The processed devices was mounted on the cold finger of the He-flow cryostat for testing. Current pulses with 950 ns width and 1.91 µs period were modulated at 413 Hz were injected into the processed devices. A few representative spectra with increasing currents at 110 K are displayed in Fig. 1(c). A peak at ~8.5 THz can be easily identified with a linewidth of ~ 20 meV, which is attributed to the bound-to-continum active region design of the structure.

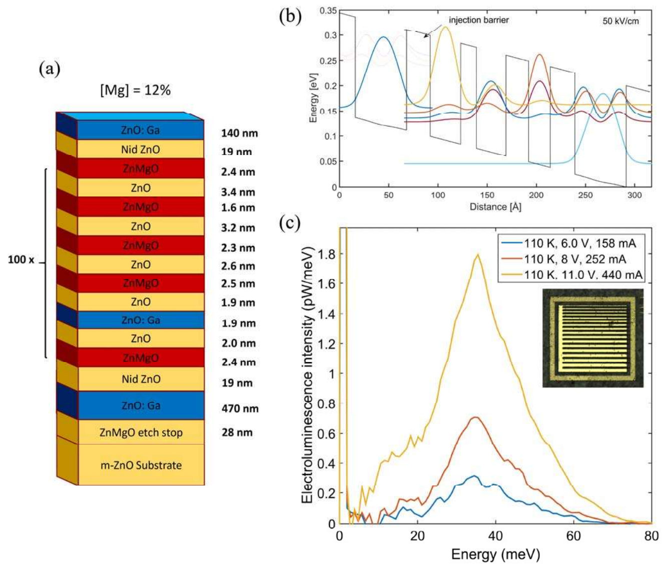


Fig. 1: (a) Layer structures of the electroluminescence sample investigated in the work. (b) Conduction band diagram of the investigated active region design under an applied electric field of 50 kV/cm at 110 K. (c) Optical spectrum of the emitted radiation for various injected currents, as indicated. The inset shows microscope image of the measured device.

III. SUMMARY

Terahertz intersubbband electrolulminescence from ZnO QC structures grown on the m-plane ZnO substrate is presented, width a linewidth of ~ 20 meV at 8.5 THz.

REFERENCES

[1]. R. Köhler *et al.*, "Terahertz Semiconductor-Heterostructure Laser," *Nature*, 417, 156, 2002.

[2]. L. Bosco, *et al.*, "Thermoelectrically cooled THz quantum cascade laser operating up to 210 K," *Appl. Phys. Lett.* 115, 010601, 2019.

[3]. V. P. Sirkeli, and H. L. Hartnagel, "ZnO-based terahertz quantum cascade lasers," *Opto-Electron. Rev*. 27, 119, 2019.

[4]. Enrico Bellotti, and Roberto Paiella, "Numerical simulation of ZnO-based terahertz quantum cascade lasers,"*J. Electron. Mater*. 39, 1097, 2010.

[5]. M. Amanti, *et al*. "Bound-to-continuum terahertz quantum cascade laser with a single quantum well phonon extraction/injection stage," *New J. Phys.* 11, 125022 (2009).

[6]. L. Diehl, *et al.*, "Electroluminescence from strain-compensated $Si_{0.2}Ge_{0.8}/Si$ quantum-cascade structures based on a bound-to-continuum transition," *Appl. Phys. Lett.* 81, 4700, 2002.