THz communication system based on a THz Quantum Cascade Laser and a Hot Electron Bolometer

F. Palma[(a)], F. Teppe[(b)], A. El Fatimy[(b)], R. Green[(c)], J. Xu[(c)], Y. Vachontin[(d)], A. Tredicucci[(d)], G. Goltsman[(d)] and W. Knap[(b)],
[(a)]NTT New Tera Technology s.r.l. (Italy)
– [(b)]CNRS, Universitè Montpellier 2 (France)
[(c)]NEST, CNR-INFM and Scuola Normale Superiore di Pisa (Italy) –
[(d)]Moscow State Pedagogical University (Russia)

Abstract — **We present the experimental study of the direct emission - detection system based on the THz Quantum Cascade Laser as a source and Hot Electron Bolometer (HEB) detector - in view of its application as an optical communication system. We show that the system can efficiently transmit the QCL Terahertz pulses. We estimate the maximal modulation speed of the system to be about several GHz and show that it is limited only by the QCL pulse power supply, detector amplifier and connection line/wires parameters.**

The Quantum Cascade Laser (QCL)[1] is one of the most promising sources of THz radiation. One of the important advantages of this type of source is that, owing to its unipolar nature, it can be modulated at very high frequencies. Until now, the emission of THz QCL was mainly probed with measurements of the mean power using slow detectors (Si bolometers, Pyroelectric detectors, Golay cells, etc.) or in cw mode as a local oscillator for superconductor Hot Electron Bolometer (HEB) mixer[2].

The modulation speed of a QCL is a very relevant parameter to apply the THz technology -especially if one considers THz communication. Of course, in order to build a whole communication system with large bandwidth, it is necessary to use also a fast detector. One of the most promising is HEB as a direct detector.

In this work we investigate the possibility of fast detection with the future aim of studying the maximal modulation speed of a realistic QCL source. HEB detectors are used to detect/visualize the QCL pulses.

We show the feasibility of an optical communication system in the Terahertz frequency range. We show how to send and modulate the radiation of the quantum cascade laser and how to detect it using a high frequency HEB.

The scheme of the experimental set – up is shown in Fig. 1
The radiation of frequency of 2.5 THz was out coupled from the QCL, guided along a ~3 m long optical path and focalized onto the HEB using four parabolic mirrors.

The signal from the detector was amplified using cold and hot amplifiers and registered using fast digital oscilloscope. Both the laser and the detector worked at cryogenic temperatures. The laser had ~10K (compressor driven cooler) and the detector ~7 K temperature, respectively (Liquid helium cooling).

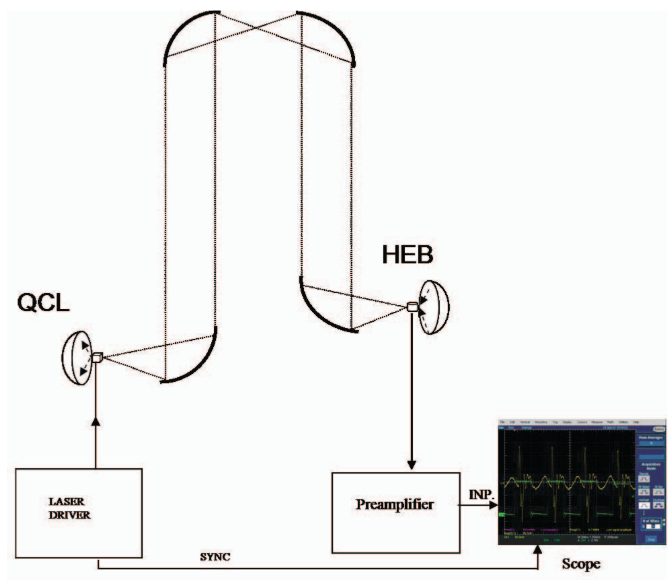

Figure 1 – Scheme of the experimental setup

The laser is driven using the commercial HP pulse generator. The waveform generator providing a square waveform at 1 kHz was used to supply a trigger time base for this generator. The pulse generator produces a sequence of bursts (about 20 bursts) with a frequency from 100 kHz up to 15 MHz. These pulses represent the signal that is sent to the receiver.
In Fig.2 we show one of the results.

The output of the receiver is sent to an oscilloscope triggered with the same time base of the pulse generator. It shows the waveform received, like in Fig 2 and 3. The pulses sent by the laser are square–like. Those detected by the bolometer are spikes with replicas. This happens because the bandwidth of the amplifying electronics in this particular case is limited to the range 10 MHz - 100 MHz.

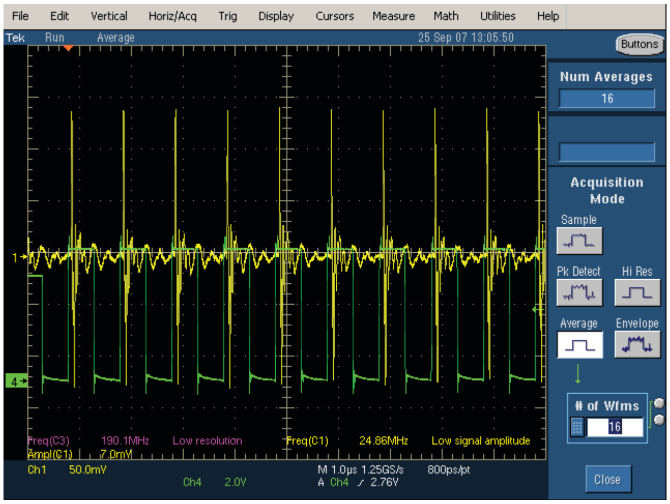

Figure 2 – Modulation @ 1MHz – time scale: 1.0µs/ division

We have observed that the receiver detects the optical pulses with high speed, following the source pulses. The most important information that should be noted at this point is that the detector indeed follows the laser pulses when we increase the frequency, as one can see from the time base of the oscilloscope indicated in the lower part of the screen in Figs. 2 and 3.

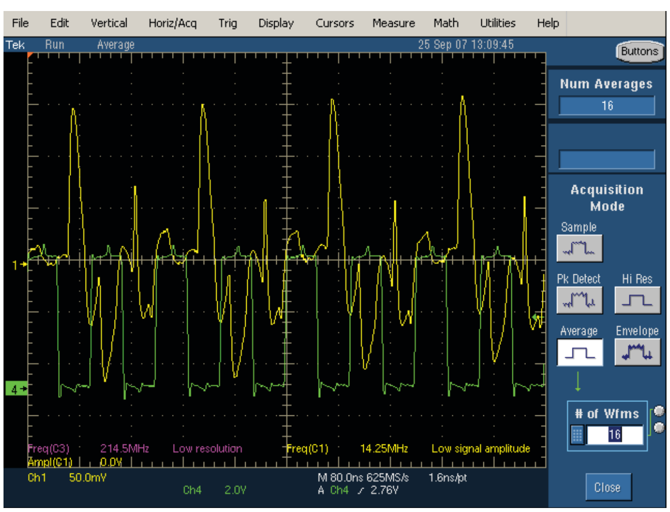

Figure 3 – Modulation @ 10MHz – time scale: 80.0ns/division

This time base is changing from 1 µs up to 200 ns indicating that effectively we reach in this experiment a fast MHz modulation. Our experimental data clearly show that already in this simple communication system, one can send information up to 15 MHz modulation frequency. It is important to mention that this experimental limit is imposed by the limit frequency of the laser power supply/pulser.

The physical limits of the modulation of QCL are in the GHz region[3] and can be surely achieved/approached while using higher frequency QCL driving pulser/power supply and impedance matched/adapted electrical connections. Also HEB as a mixer shows 3-4 GHz bandwidth that can be extended up to 6 GHz[4] by using another HEB broadband amplifier

In conclusion, our experiments prove that it is feasible to build a fast optical/radio link for a distance of a few meters using THz radiation emitted by a QCL as source and an HEB as detector. In our particular case, the maximum speed of modulation of the laser is limited to MHz range by the driving electronics, cables connectors, etc. Improving the QCL power supply/pulser and the detection electronics can lead to the system with modulation frequencies in the GHz range.

ACKNOWLEDGMENTS

The authors from Montpellier University acknowledge the CNRS guided GDR-I projects "*Semiconductor sources and detectors of THz frequencies*". They also acknowledge the JST-ANR project *"WIreless communication using TeraHertz plasmonic-nano ICT devices"*

REFERENCES

[1] B. S. Williams, "Terahertz quantum cascade lasers," Nature Photon. **1**, 517-525 (2007).
[2] E.M.Gershenzon, G.N.Gol'tsman, I.G.Gogidze, Yu.P. Gousev, A.I.Elant'ev, B.S.Karasik, and A.D.Semenov, Sov. Phys. Superconductivity 3, 1582 (1990)
[3] Stefano Barbieri, Wilfried Maineult, Sukhdeep S. Dhillon, Carlo Sirtori, Jesse Alton, Nicolas Breuil, Harvey E. Beere, and David A. Ritchie "13 GHz direct modulation of terahertz quantum cascade lasers" Appl. Phys. Lett. 91, 143510 (2007)
[4] Ryabchun S.A., Tretyakov I.V., Finkel M.I., Maslennikov S.N., Kaurova N.S., Seleznev V. A., Voronov B. M., Goltsman G. N., Proc. "19th international symposium on space terahertz technology", pp. 62-67, 2008.