Optically modulated Quantum Cascade Laser – progress towards a frequency comb in the MIR

R. Martini[1], Tao Yang[1], Seong-Wok Park[1], Chao Tian[1], Gang Chen[1]

[1]*Dept. Of Physics and Engineering Physics, Stevens Institute Of Technology,*
1 Castle Point on Hudson, Hoboken, New Jersey 07030, USA
E-mail: rmartini@stevens.edu

We demonstrate the use of optical non-resonant illumination of the front facet of quantum cascade lasers for fast wavelength modulation with the potential of pure frequency modulation. In addition a frequency comb can be generated by optical modulation with Ti:Sapphire laser pulses.

1. Introduction

Middle infrared (MIR) Quantum Cascade Lasers (QCL) [1] have a great potential for spectroscopy due to their high output power, narrow linewidth, and high frequency tuneability. Yet control of the emission wavelength is restricted mainly to a slow temperature or external laser cavity tuning – assisted by indirect wavelength tuning through the heating of the laser based on the current flow.

Yet as most standard spectroscopy techniques have been successfully employed using QCLs, a few promising techniques require more direct control of the lasing mechanism. One example is the utilization of frequency comb generation, which has been extremely successful in optical meteorology and clocks and has recently become a promising spectroscopy technique as well [2] – but requires stable and controlled mode-lock operation of the laser. Here we suggest a novel different approach through optical modulation of the QCL front facet.

2. Optical Modulation

Optical modulation of QCLs has already been demonstrated to allow direct and high-speed modulation of the emission intensity [3] as well as the emission frequency [4]. The inset of figure 1 shows exemplary the frequency response of an 8μm QCL under optical illumination with 100fs short pulses – whereby the detection bandwidth was limited to 8GHz due to the detector. As the signal shows a broadband response with frequencies beyond 10 GHz, a more detailed analysis reveals a discrete emission spectrum consisting of more than 110 harmonics of the 87MHz repetition frequency originating from the modulating Ti:Sapphire laser pulses – as exemplary demonstrated by the 10.35 GHz component shown in the main part of figure 1. This observation proofs the generation of the frequency comb already, and we will discuss and present application of this comb to spectroscopy.

3. Further application

In addition we will present recent developments, which show that same approach can be applied to NIR laser technology as well, allowing generating optical as well as electric modulation of fiber coupled diode laser operating in the 800nm and 1550 nm region. Pure frequency modulation without amplitude modulation can thereby achieved through combination with electrical modulation, which has application in spectroscopy as well as in communication technology.

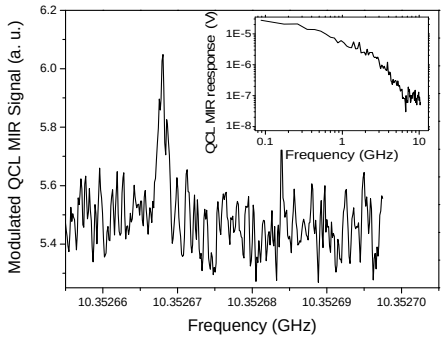

Fig. 1: Inset: Frequency response for optical modulation of QCL, Main: 10GHz component of the modulation response.

References

[1] J. Faist, D. L. Sivco, C. Sirtori, A. L. Hutchinson, and A. Y. Cho, "Quantum Cascade Laser", Science New Series, **264**, p. 553 (1994).

[2]M.J. Thorpe, K.D. Moll, R.J. Jones, B. Safdi, and J. Ye, "Broadband cavity ringdown spectroscopy for sensitive and rapid molecular detection". Science Vol. 311 pp. 1595 (2006)

[3] Chen G, Martini R, Park S-, Bethea CG, Chen I-A, Grant PD, Dudek R, Liu HC. "Optically induced fast wavelength modulation in a quantum cascade laser", Appl Phys Lett 97(1), p. 011102 (2010).

[4] Chen G, Bethea CG, Martini R, Grant PD, Dudek R, Liu HC, "High-speed all-optical modulation of a standard quantum cascade laser by front facet illumination", Appl Phys Lett **95**, p. 101104 (2009).