



Deposited via The University of Leeds.

White Rose Research Online URL for this paper:

<https://eprints.whiterose.ac.uk/id/eprint/106100/>

Version: Presentation

Conference or Workshop Item:

Agnew, G, Grier, A, Taimre, T et al. Prediction of Turn-on Delay in a Pulsed Terahertz Quantum Cascade Laser. In: 13th International Conference on Optoelectronics and Microelectronic Materials and Devices (COMMAD2016), 12-14 Dec 2016, Sydney, Australia. (Unpublished)

This abstract is an author produced version of a conference paper originally presented at the 13th International Conference on Optoelectronic and Microelectronic Materials and Devices, Sydney, Australia, 12-14 December, 2016.

Reuse

Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.

Prediction of Turn-on Delay in a Pulsed Terahertz Quantum Cascade Laser

Gary Agnew¹, Andrew Grier², Thomas Taimre^{3,1}, Yah Leng Lim¹, Karl Bertling¹, Zoran Ikonić², Alexander Valavanis², Paul Dean², Jonathan Cooper², Suraj P. Khanna², Mohammad Lachab², Edmund H. Linfield², A. Giles Davies², Paul Harrison⁴, Dragan Indjin², and Aleksandar D. Rakić^{*1}

¹School of Information Technology and Electrical Engineering, The University of Queensland, Brisbane, QLD 4072 Australia

²School of Electronic and Electrical Engineering, University of Leeds, Leeds LS2 9JT~UK

³School of Mathematics and Physics, The University of Queensland, Brisbane, QLD 4072 Australia

⁴Materials and Engineering Research Institute, Sheffield Hallam University, Sheffield S1 1WB~UK

*Corresponding author: rakić@itee.uq.edu.au

Précis- The response time of terahertz (THz) quantum cascade lasers (QCLs) is of prime importance in high speed pulsed applications. Response times of typical THz QCLs are in the picosecond range, making their study in the laboratory difficult. An alternative means of exploring QCL turn-on dynamics is the use of an accurate rate equation model. In this work we present turn-on delay characteristics predicted by an accurate model of a 2.59 THz bound-to-continuum QCL.

To date, model-based investigations of start-up delay, rise time, and overshoot characteristics of THz QCLs have made use of rate equations with fixed parameters, yielding results that are valid over a limited current and active region temperature range [1]. While such results are informative with respect to the general behavioral trends of QCLs, they do not provide the device-specific insight required to inform detailed application design. Here we demonstrate the use of an accurate, device-specific reduced rate equation (RRE) model [2], [3] to characterize the turn-on dynamics of a 2.59 THz bound-to-continuum QCL [4]. Figure 1 shows the optical output power response of the QCL to a 1.2 ns rectangular drive current pulse of amplitude 460 mA. The cold finger operating temperature used was 15 kelvin. Petermann's definition [5] of laser turn on time was used. The simulation was repeated at five temperatures (15, 35, 40, 45, 50, and 52 K) and three drive currents, 460, 470, and 480 mA, to produce the characteristics shown in Fig. 2. A future thrust of this research will be laboratory work designed for indirect observation of THz QCL dynamical metrics such as turn-on delay, pulse rise time, and modulation bandwidth, to be validated against the predictions of our RRE model.

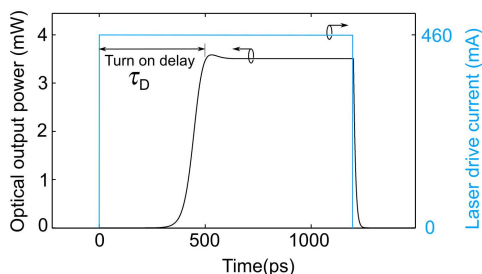


Fig. 1. Optical output response of QCL to a current step of 460 mA at 15 kelvin, showing turn on delay and overshoot.

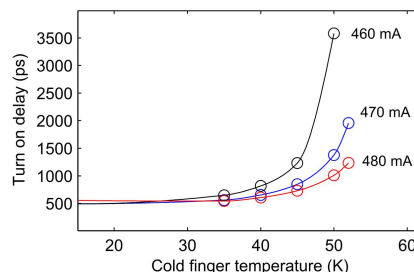


Fig. 2. Dependence of QCL turn-on delay on temperature and drive pulse magnitude.

[1] A. Hamadou, S. Lamari, and J. L. Thobel, "Dynamic modeling of a midinfrared quantum cascade laser," *J. Appl. Phys.* **105**, 093116 (2009).

[2] G. Agnew, A. Grier, T. Taimre, Y. L. Lim, M. Nikolić, A. Valavanis, J. Cooper, P. Dean, S. P. Khanna, M. Lachab, E. H. Linfield, A. G. Davies, P. Harrison, Z. Ikonić, D. Indjin, and A. D. Rakić, "Efficient prediction of terahertz quantum cascade laser dynamics from steady-state simulations," *Appl. Phys. Lett.* **106**, 161105 (2015).

[3] G. Agnew, A. Grier, T. Taimre, Y. L. Lim, K. Bertling, Z. Ikonić, A. Valavanis, P. Dean, J. Cooper, S. P. Khanna, M. Lachab, E. H. Linfield, A. G. Davies, P. Harrison, D. Indjin, and A. D. Rakić, "Model for a pulsed terahertz quantum cascade laser under optical feedback," *Opt. Express* **24**, 20554-20570 (2016).

[4] A. D. Rakić, T. Taimre, K. Bertling, Y. L. Lim, P. Dean, D. Indjin, Z. Ikonić, P. Harrison, A. Valavanis, S. P. Khanna, M. Lachab, S. J. Wilson, E. H. Linfield, and A. G. Davies, "Swept-frequency feedback interferometry using terahertz frequency QCLs: A method for imaging and materials analysis," *Opt. Express* **21**, 22194-22205 (2013).

[5] K. Petermann, *Laser Diode Modulation and Noise* (Kluwer, 1991).