# Highly Sensitive Detection of Organic Molecules using Widely Electrically Tuneable QCLs

**Lukas Emmenegger[1], Oleg Aseev[1,3], Philipp Scheidegger[1] Stéphane Blaser[2], Herbert Looser[1] and Béla Tuzson[1]**

*1 Empa, Laboratory for Air Pollution / Environmental Technology, CH-8600 Dübendorf, Switzerland*
*2 Alpes Lasers SA, Avenue des Pâquiers 1, 2072 St-Blaise, Switzerland*
*3 MIRO Analytical Technologies, CH-8600 Dübendorf, Switzerland*
*Email: lukas.emmenegger@empa.ch*

**Abstract:** Widely electrically tuneable QCLs are highly attractive for the sensitive and selective detection of organic molecules. Both high spectral resolution and broad coverage are shown for an XT-QCL providing 6-channels based on the Vernier effect. 
**OCIS codes:** Atmospheric and oceanic optics: 010.1120 Air pollution monitoring, Lasers and laser optics: 140.5965 Semiconductor lasers, quantum cascade, Spectroscopy: 300.6340 Spectroscopy, infrared.

## 1. Introduction

Volatile organic compounds (VOCs) are ubiquitous in our environment and everyday life. Their selective and precise detection is thus of great interest in many industrial, environmental, medical, and forensic applications.

VOCs exhibit typically broad and congested ro-vibrational spectral features. This makes their measurement by laser absorption spectroscopy using conventional DFB-QCLs challenging because of the narrow tuning range of such devices. External cavity QCLs (EC) show a much larger tuning range, however, at the price of other limitations, such as reduced tuning rate, mode hops, mechanical instabilities, lower resolution, and higher cost. Recently, broadband, electrically tuneable QCL devices became available, such as Extended Tuning (ET) [1] and Very Large Tuning (XT) [2] QCLs.

## 2. Experimental

Distributed Bragg reflectors based on superstructure gratings are used to realize the Vernier effect. Modifying the temperature of the DBRs by applying current on the integrated heaters allows switching from one Vernier channel to the other, while predictable and mode-hop free tuning can be obtained within each channel modulating the laser current. This results in a switchable multi-channel tunable source. Such devices are highly attractive because they can be used for high-resolution spectroscopy simultaneously in several channels, as shown in Fig. 1. This is advantageous when molecules have overlapping spectral features that may not be sufficiently distinguished within the tuning range of a single DFB.

Here we present the application of ET-QCLs and XT-QCLs for the selective measurement of organic molecules, such as ethanol, methanol, and isopropanol. An intermittent CW (iCW) driving scheme [3], originally developed in our laboratory for DFB-QCL, was adapted to achieve fast scanning, rapid switching, and wide tuning of these devices resulting in quasi continuous spectral coverage.

This is demonstrated for an XT-QCL with 6 channels covering 40 cm-1 for the selective measurement of methanol, ethanol, and acetaldehyde in the range of 50 – 100 ppm. The XT-QCL was kept at 15°C and driven with 700 mA current in all regimes. Allan-Werle deviation analysis shows that the target substances can be detected with a precision below 50 ppb (100 s averaging), and that the combination of several detection channels is valuable both in terms of selectivity and sensitivity.

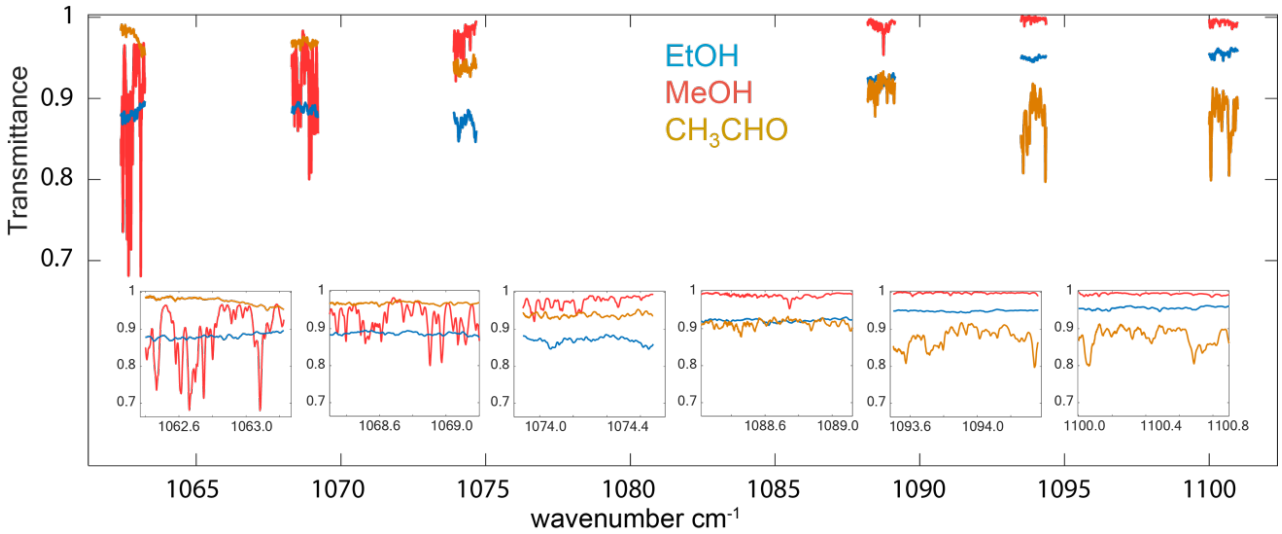


Fig. 1: Absorption spectrum of a VOC mixture recorded using an XT-QCL. Individual channels are scanned successively by adjusting the DBR currents after the acquisition of each high-resolution spectrum. Single channel scanning takes 50 µs. A complete scan cycle is 18 ms, given by the slow DBRs thermal response.

We also show that conventional DFB-QCLs are under certain conditions well suited for high-precision measurements of VOCs. As an example, we demonstrate highly selective and sensitive measurements of ethanol in a breath-like gas matrix (including 5.0 % of CO2 and 5.4 % of H2O) – the most widely employed forensic application [4].

### 3. Conclusions

Highly resolved mid-IR spectroscopy is valuable, even for organic molecules that exhibit broad absorption features. Intermittent continuous wave (iCW) tuning allows obtaining the best spectral coverage from single DFB-QCLs, and Vernier-based XT-QCLs provide the equivalent of several DFB-QCLs in one electrically tunable device. This yields the selective and sensitive detection of organic molecules, in a setup that contains no mechanical parts, and which may be suitable for a wide range of applications.

## References:

[1] A. Bismuto, Y. Bidaux, C. Tardy, R. Terazzi, T. Gresch, J. Wolf, S. Blaser, A. Muller, and J. Faist, Optics Express, 23, 23 (2015).
[2] Y. Bidaux, A. Bismuto, C. Tardy, R. Terazzi, T. Gresch, S. Blaser, … J. Faist, Appl. Phys. Lett., 107, 22 (2015).
[3] M. Fischer, B. Tuzson, A. Hugi, R. Brönnimann, A. Kunz, S. Blaser, M. Rochat, O. Landry, A. Müller, and L. Emmenegger, Opt. Express, 22 (2014).
[4] O. Aseev, B. Tuzson, H. Looser, P. Scheidegger, C. Liu, C. Morstein, B. Niederhauser and L. Emmenegger, Opt. Express, in press (2019).