TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Research Group on Process Analysis & Vibrational Spectroscopy
CTA Institute of Chemical Technologies and Analytics

Nanosecond step-scan FTIR spectroscopy of a pulsed external-cavity quantum-cascade laser

Markus Brandstetter, Andreas Genner, Bernhard Lendl

Institute of Chemical Technologies and Analytics, Vienna University of Technology, Getreidemarkt 9, A-1060 Vienna, Austria

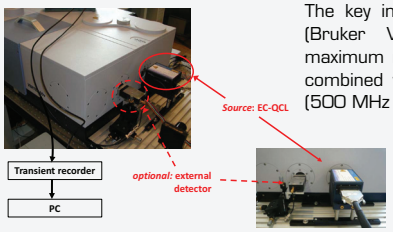
Introduction

Quantum cascade lasers (QCLs) as a source for high-intensity infrared radiation enable successful spectroscopical measurements of strong absorbers with high pathlengths. A typical example would be measurements in aqueous solutions. QCLs built in external-cavity design (EC-QCL) additionally provide a tunable emission spectrum which offers the possibility of recording **several absorption bands with a single laser**.

Several applications require detailed information about the infrared radiation source, both in spectral and time domains. To match this task a high resolution FTIR spectrometer was combined with a fast transient recorder board to perform highly-resolved step-scan measurements.

The investigated laser was a **pulsed EC-QCL** with a tunable spectral range of over **200 cm^{-1}** and a maximum power output of **360 mW.**

Measurement setup



The key instruments were a **vacuum FTIR** (Bruker Vertex 80v) with 0.07 cm^{-1} maximum resolution and a **fast IR-detector** combined with a **transient recorder board** (500 MHz acquisition rate, 8 bit resolution).

The EC-QCL was operated with a 100 kHz repetition rate. Step-scan triggering was done by the laser.

A **LabVIEW-based interface** controlled the EC-QCL driver and configured the laser parameters, e.g. the driving current and the pulse width.

Nanosecond time resolved mid-IR laser pulses

Step-scan measurements provide valuable information about the EC-QCLs emission characteristics during single laser pulses. The pulse lengths of the mid-IR laser were adjusted between 40 ns and 500 ns.

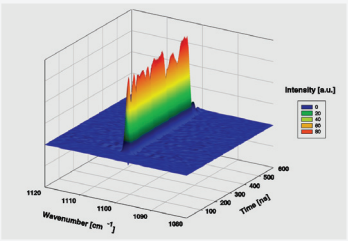


Figure 1: Step-scan measurement of a 500 ns laser pulse (3D-view)

The spectral **and** time characteristics of the mid-IR laser source could be determined at an optimal resolution:

Time resolution: 2 ns
Spectral resolution: 0.1 cm^{-1}

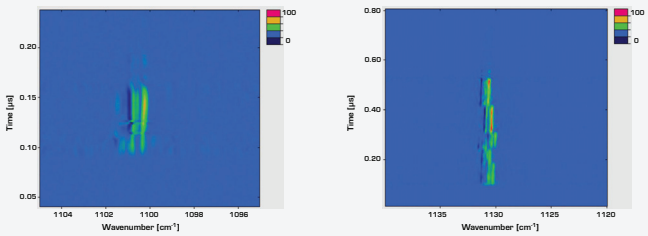


Figure 2: Comparison of a short (40 ns, left) and a long (400 ns, right) infrared laser pulse, recorded by step-scan measurements (2D-view).

The measurement results delivered detailed information about the laser operation performance. **Mode-hopping**, **spectral stability** and **pulse form** could be quantified for the whole EC-QCL operating range.

Spectral tuning of the EC-QCL

The investigated EC-QCL offered **two operating modes**:

- A **step-wise** change of the emission wavenumber
- A **quasi-continuous** variation of the emission wavenumber (whole range in <1 s)

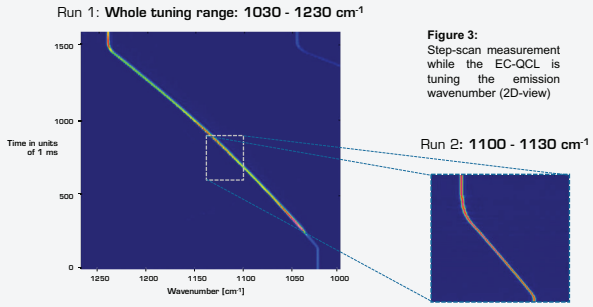
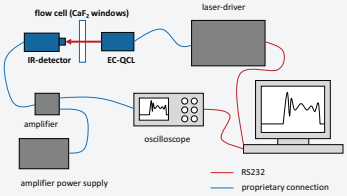


Figure 3: Step-scan measurement while the EC-QCL is tuning the emission wavenumber (2D-view)

A major benefit of the quasi-continuous mode is the possibility to record a whole spectrum in **less than 2 s**. This is possible because the step-scan measurements in Fig. 4 are a kind of calibration line, relating every point in time to a distinct emission wavenumber. An **interferometer** is **no longer required.**

Applications: EC-QCL based liquid phase spectroscopy

Knowledge of the QCL's spectral characteristics allows their application for **high intensity spectroscopy**.



Elementary experimental setup:

- Pulsed EC-QCL (360 mW average pulse power)
- Flow cell with **27 - 200 µm pathlength**
- Thermoelectrically-cooled MCT-detector
- BoxCar system / DSP-board
- **LabVIEW-interface**

The results of preliminary measurements, e.g. with Ringer-lactate ($c_{lactate}$= 28 mmol/l) confirmed the ability of the EC-QCL setup to perform mid-IR spectroscopy of aqueous solutions with pathlengths **up to 200 µm**.
A standard deviation lower than 0.5 % could be achieved.

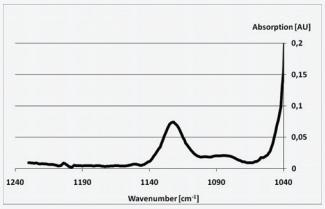


Figure 4: Ringer-lactate in a 150 µm pathlength flow cell