IRSENS

Méthodes optiques pour l'analyse des gaz et des liquides, e.g. détection de cocaïne dans la salive

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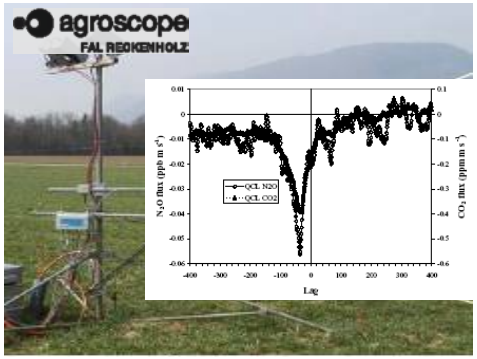
Nano-Tera.ch Info Day 2014

Sensing needs



Environment

Air quality control

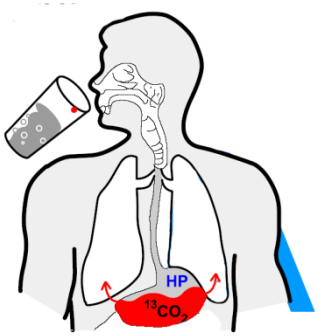
Leak detection

Gases **fluids**

Sensing of small molecules
(CO, CO_2, N_xO_y, ...)

Selective
Sensitive

Portable
Low power

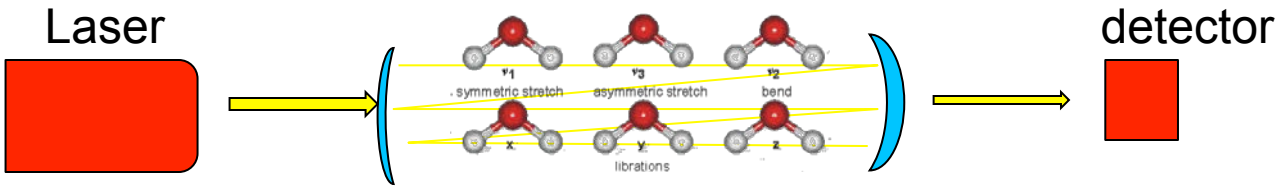


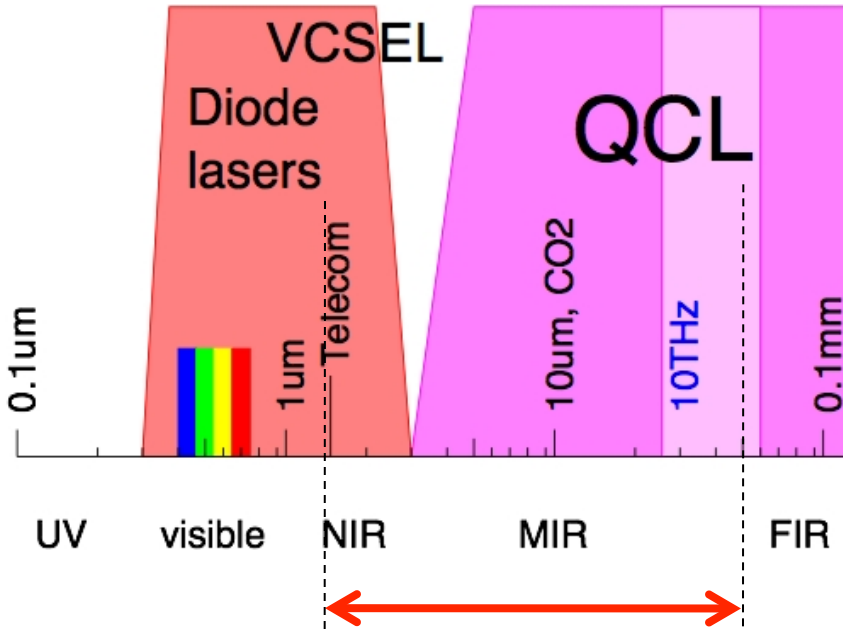
Medical diagnosis

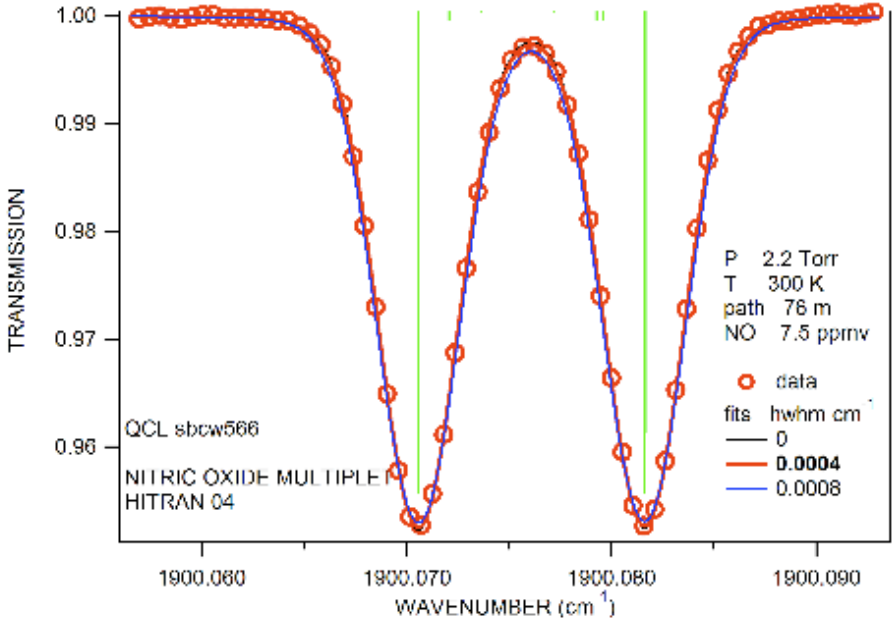
Drug monitoring

Traffic security

Approach: optical sensing







IrSens

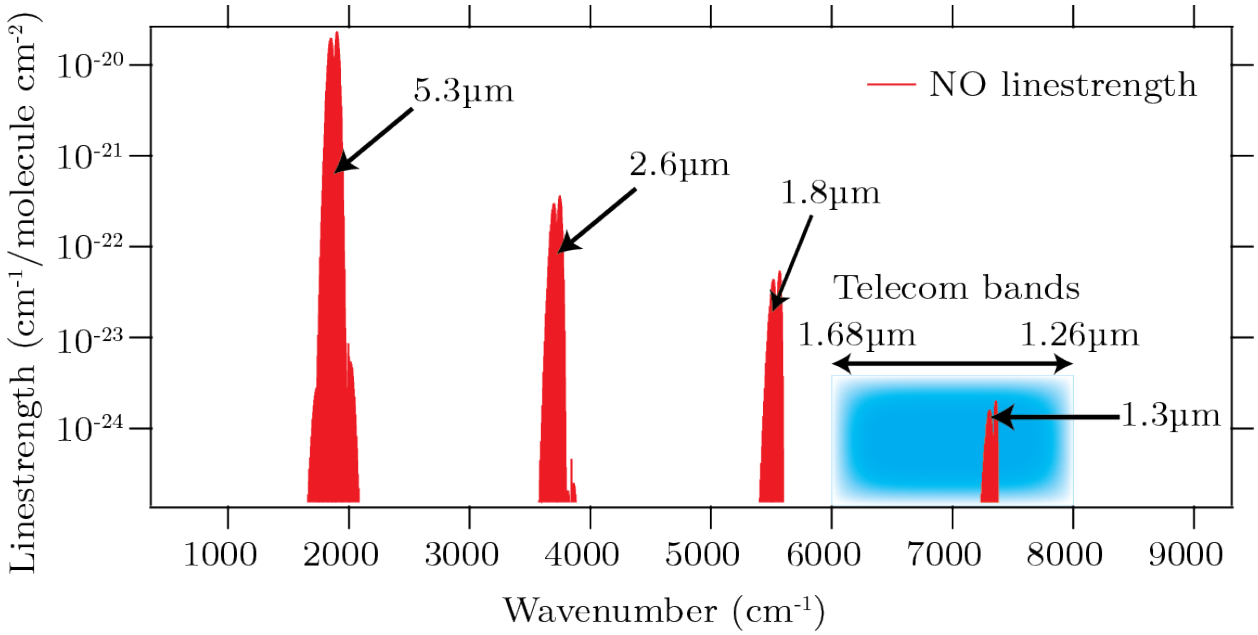
Why the mid-infrared?

The mid-IR spectral range

- 2.5 µm < λ < 25 µm (4000 cm^{-1} – 400 cm^{-1})
- Access fundamental roto-vibrational states of molecules
- Atmospheric windows (3.5-4.8 µm / 8-12 µm)

Applications

- Medicine
- Sensing
- Emission monitoring
- Process control
- Free-space communication
- Defense
- Homeland security



Photonics: an expensive solution?

Preconception #1: Optics means lenses, alignement, and therefore is expensive

Contains a single mode laser, lens Detector(s). Retail price: ~10CHF

Contains a single laser, high NA lens, tracking mechanism, detector, etc..
Retail price: ~50CHF

Mid-Infrared: immature?

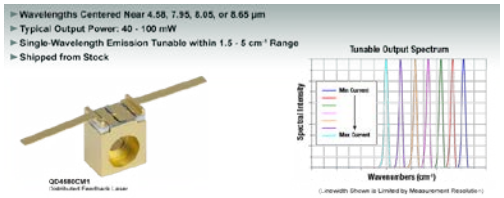
Preconception #2: Mid-Infrared is not mature, no lenses, no fibers, bad detectors, expensive lasers

Detector:

20pW NEP
TEC cooled

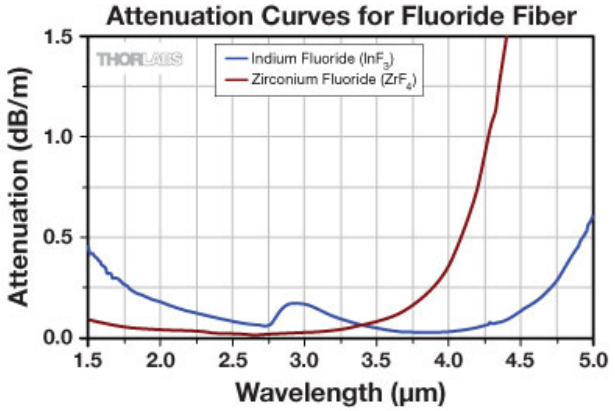
Aspheres with NA up to 0.8

Quantum cascade lasers

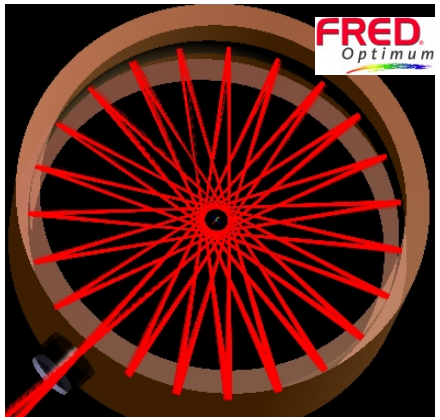


Alpes Laser, Hamamatsu, Thor Labs, …

Fibers



Gas sensor: block diagram



Source: DFB Quantum Cascade Laser

Interaction system: cylindrical mirror cell

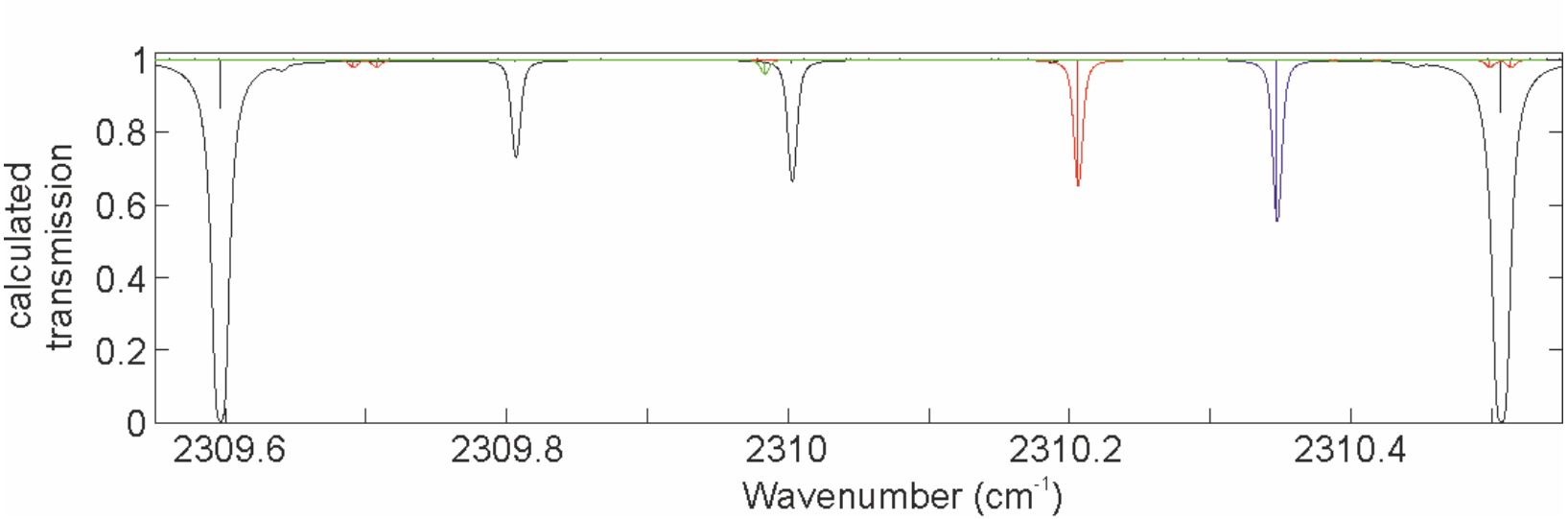
Detection: Quantum Cascade Detector

Goal: all parts have a low production cost in large volume

Compared to “standard” systems:
- Replace MCT detector with III-V based quantum cascade detector
- Develop a new interaction cell

Measurements in Gases

Absorption Signature of CO_2 Isotopes



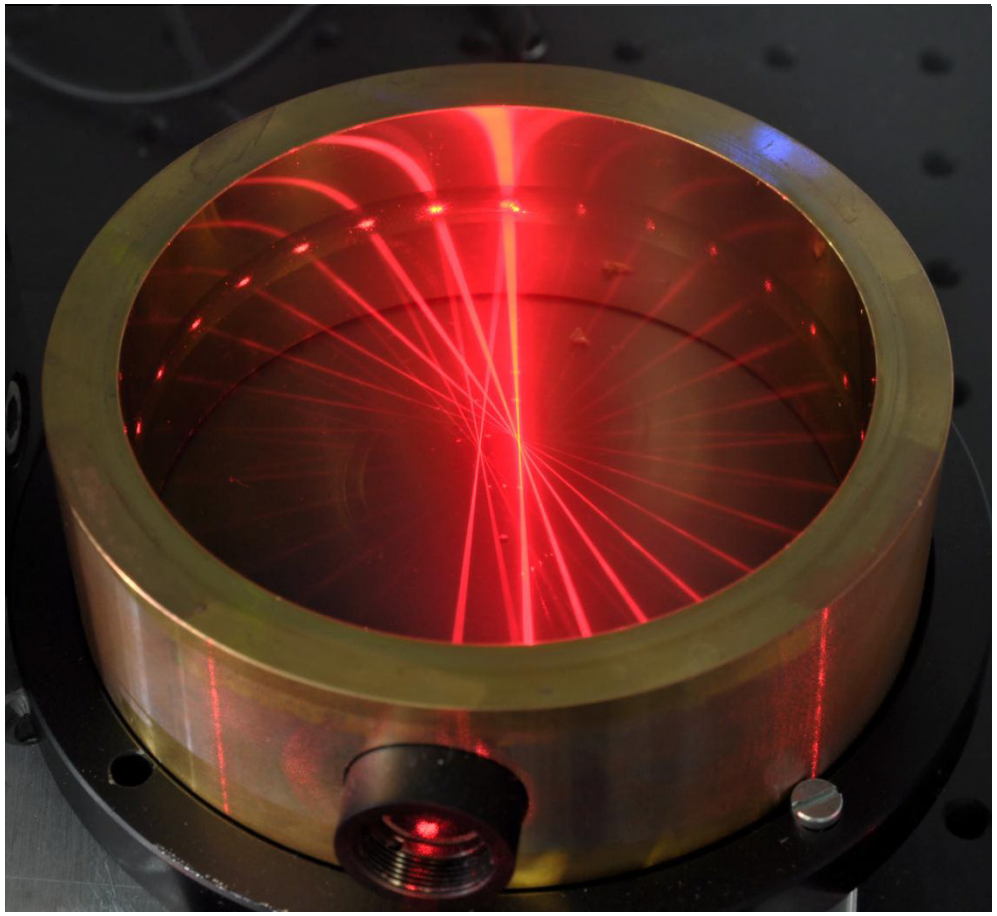
$^{12}C^{16}O_2$: Main isotope.

$^{13}C^{16}O_2$: indicator for heliobacter pyroli → stomach cancer

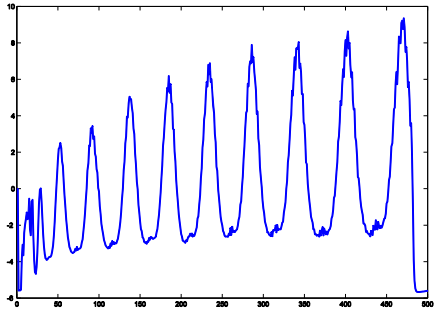
$^{18}O^{12}C^{16}O$: quantify soil exchange processes.

$^{17}O^{12}C^{16}O$: tracer for stratospheric air.

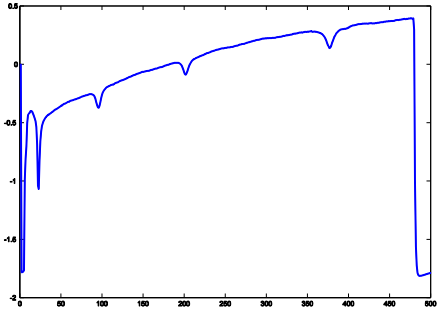
Gas sensor: toroidal cell with «Fringe Killer»



Without absorption mask
-> interference, fringes



With absorption mask



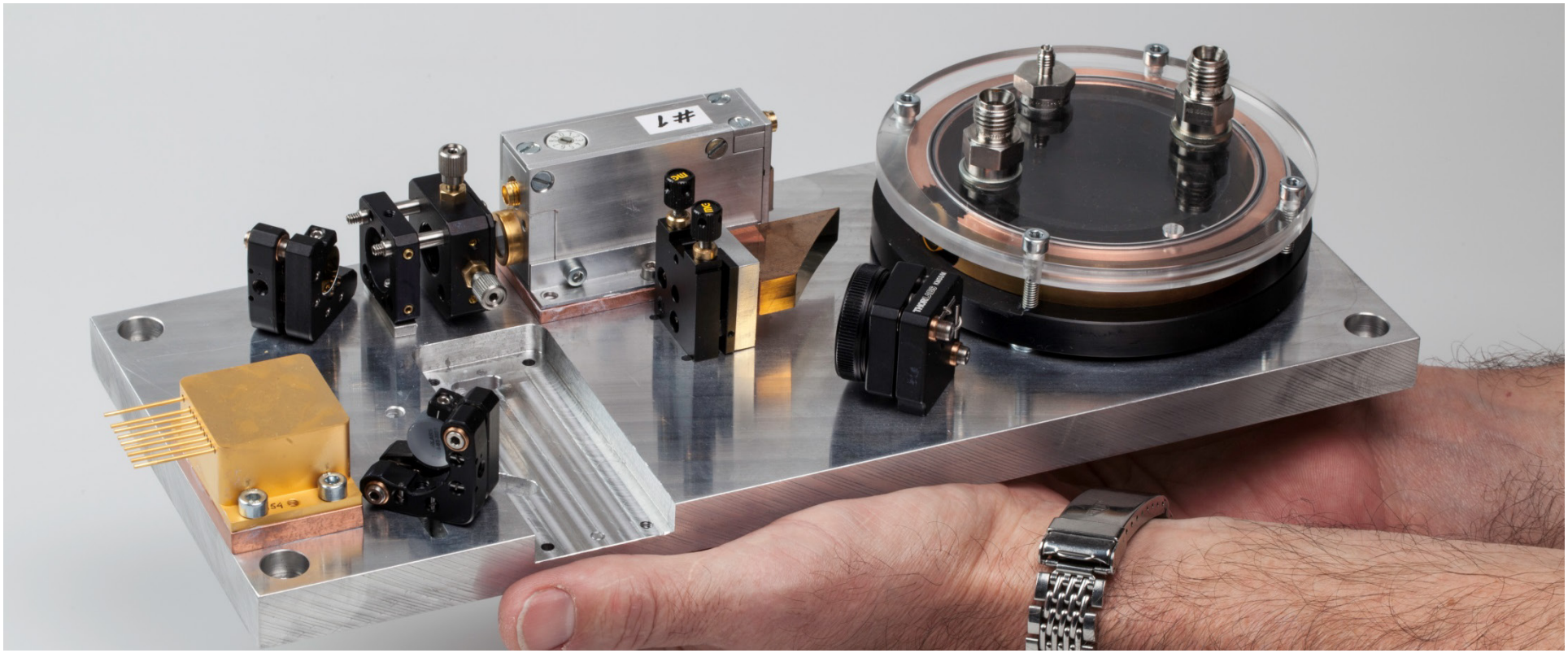
A patent was filed protecting the use of an absorption mask in a gas cell for MIR laser spectroscopy.

EMPA
Materials Science & Technology

B. Tuzson, M. Mangold, H. Looser, A. Manninen, L. Emmenegger, Opt. Lett. **38**, 257 (2013).

M. Mangold, B. Tuzson and L. Emmenegger, "Method for reducing fringes in laser spectroscopy measurements using an absorption mask in combination with multi-pass optical cells". Switzerland Patent 01884/12, 2012.

Gas sensor: packaging



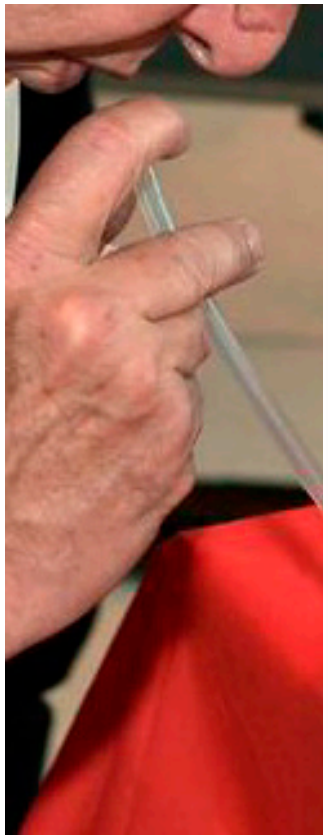
Gas sensor: packaging

Light source: a quantum cascade laser

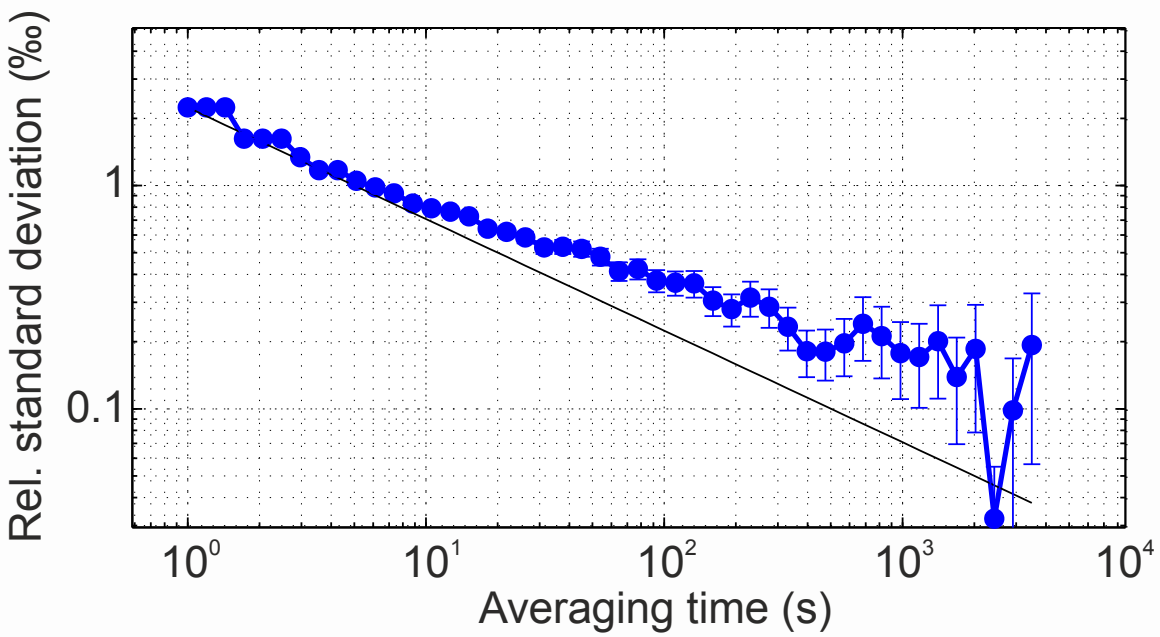
Interaction system: a multipass reflection cell

Light detector: a quantum cascade detector

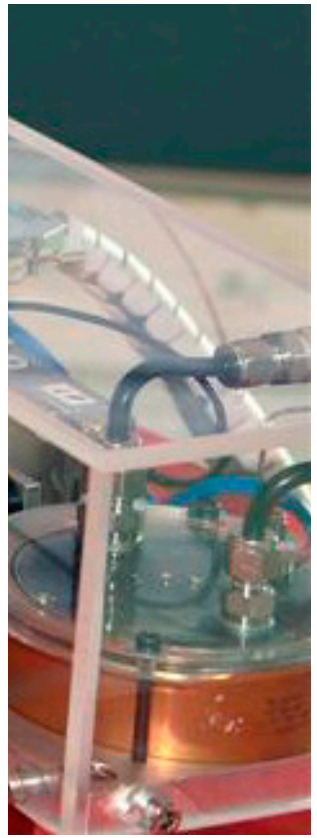
Ultra-compact CO_2 isotope analyzer



$^{13}CO_2$ to $^{12}CO_2$ isotope ratio measurements

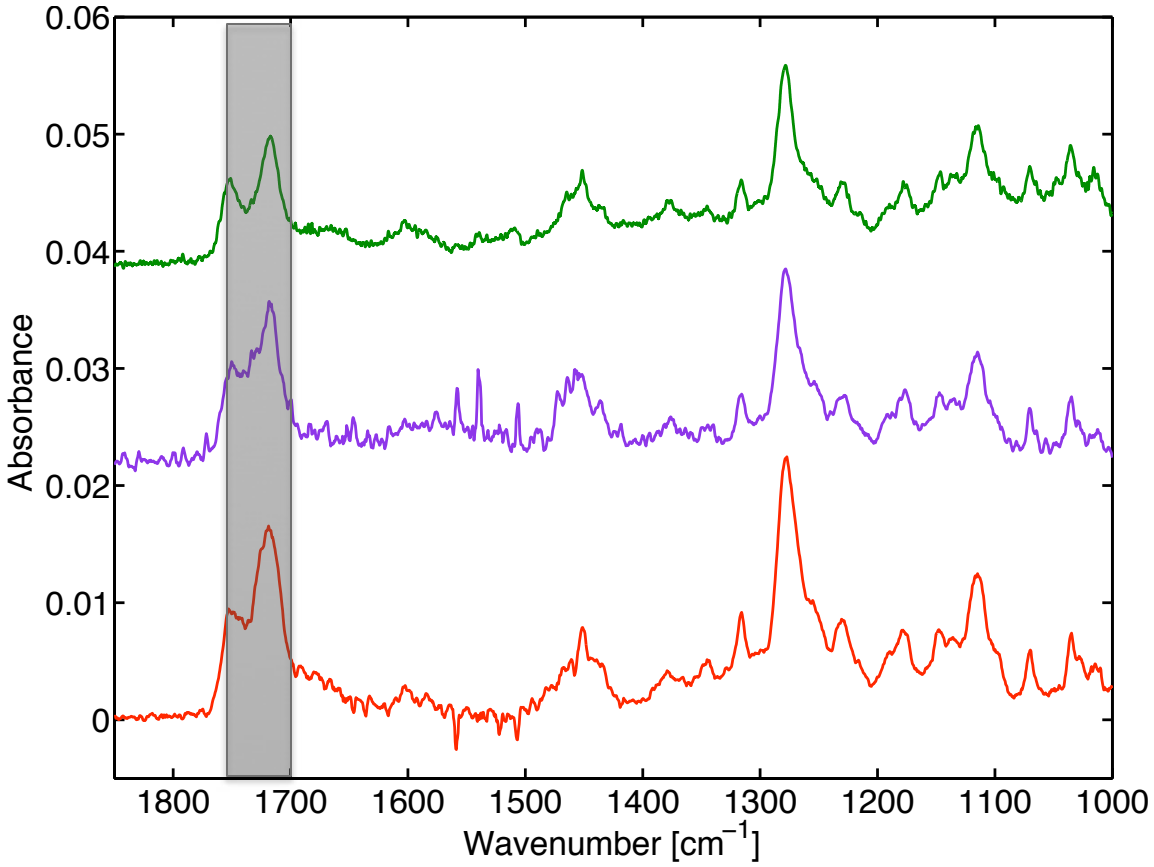


Isotope ratio measurement precision of 0.2 ‰.



Measurements in Liquids

Measurements in liquids: benchmarking with FTIR

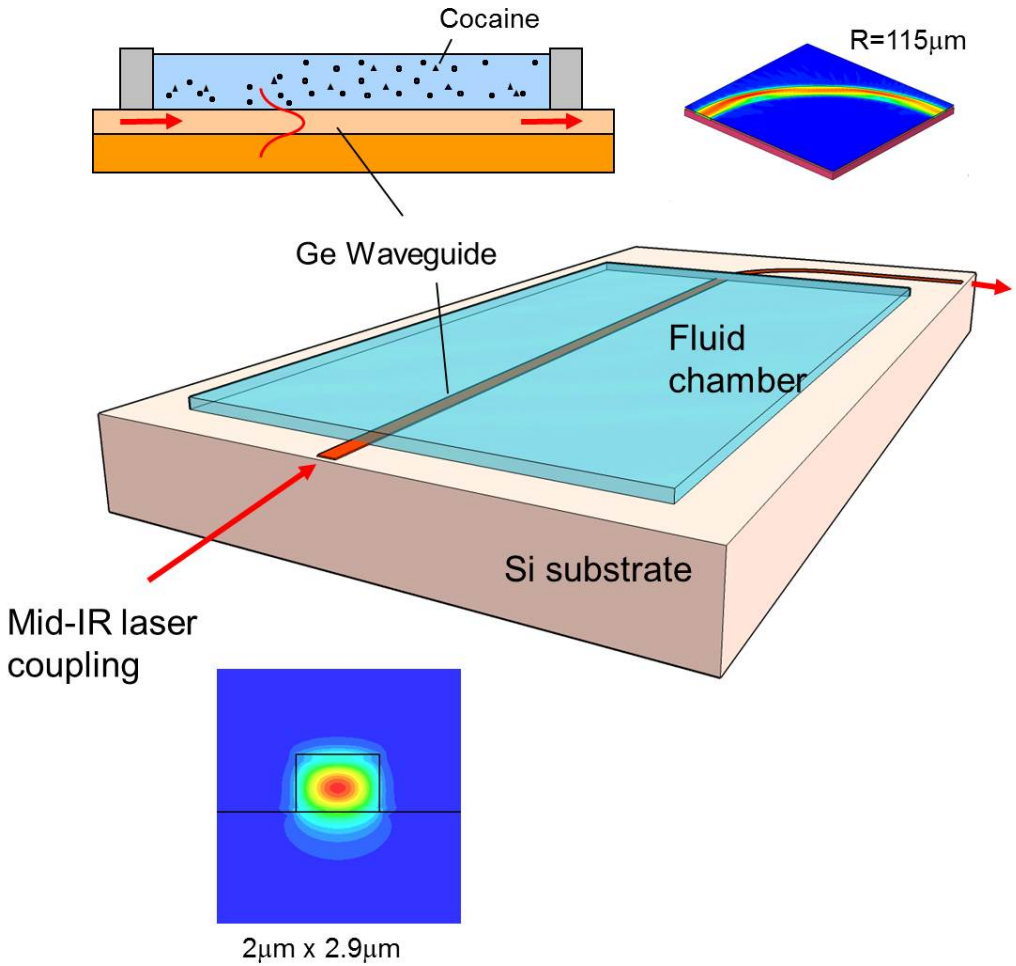


ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

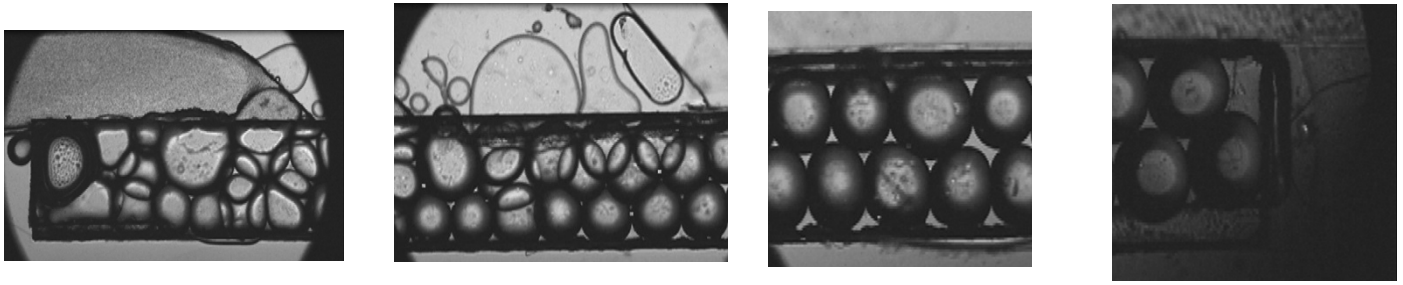
Comparison between spectra of pure cocaine, TCE phase of an extract from saliva spiked with pure cocaine and of an extract of saliva spiked with street cocaine (from the Forensic Science Institute Zurich)

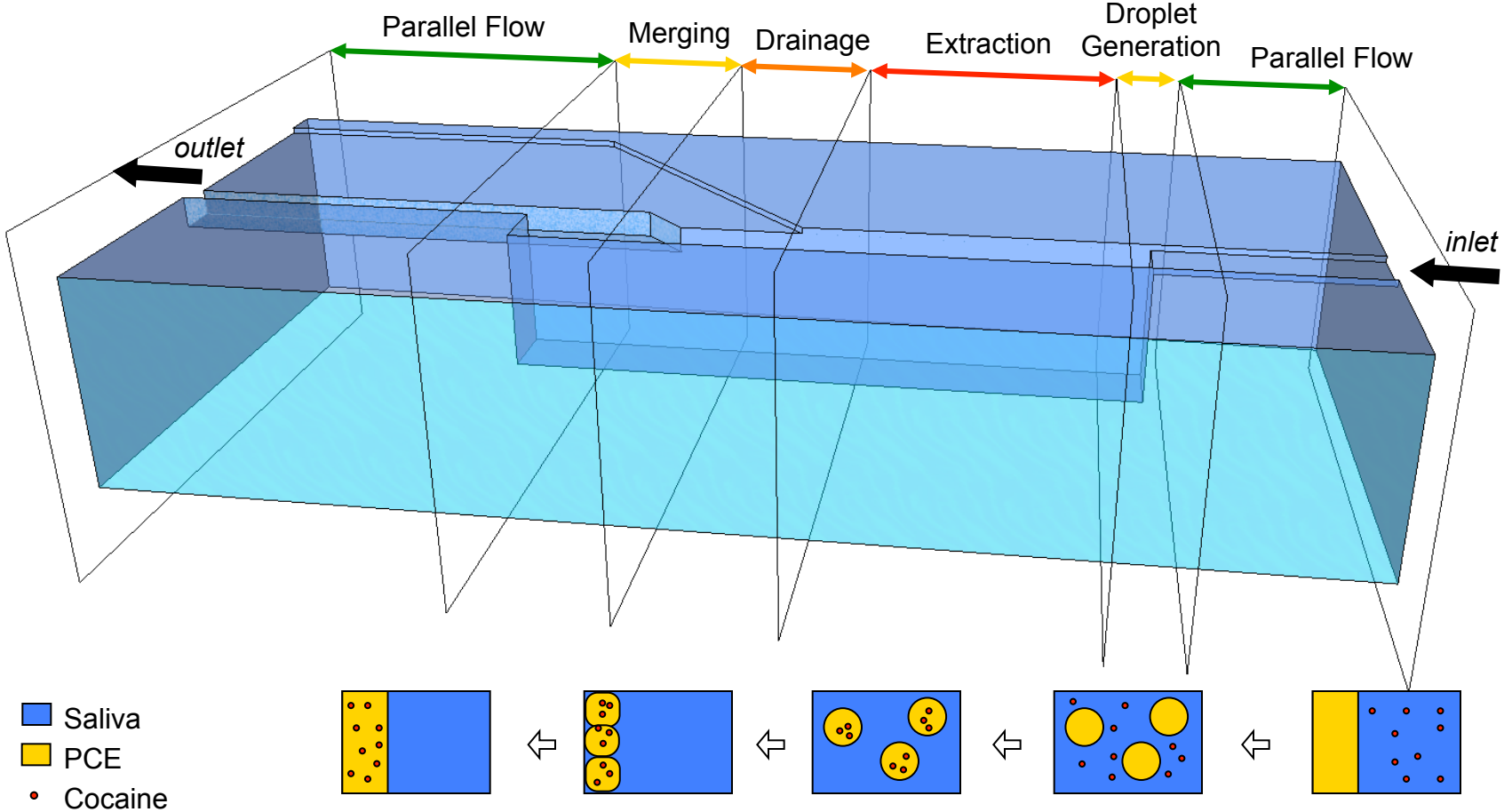
Measurements in liquids: Si/Ge waveguides

Evanescence interaction:



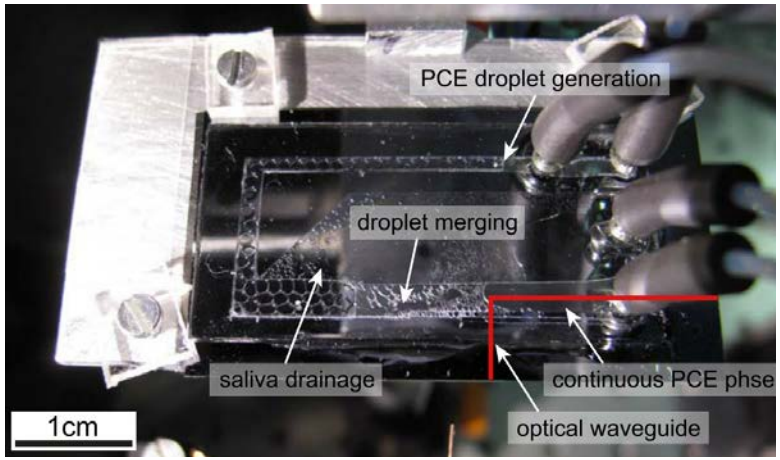
Measurements in liquids: real microfluidic extraction

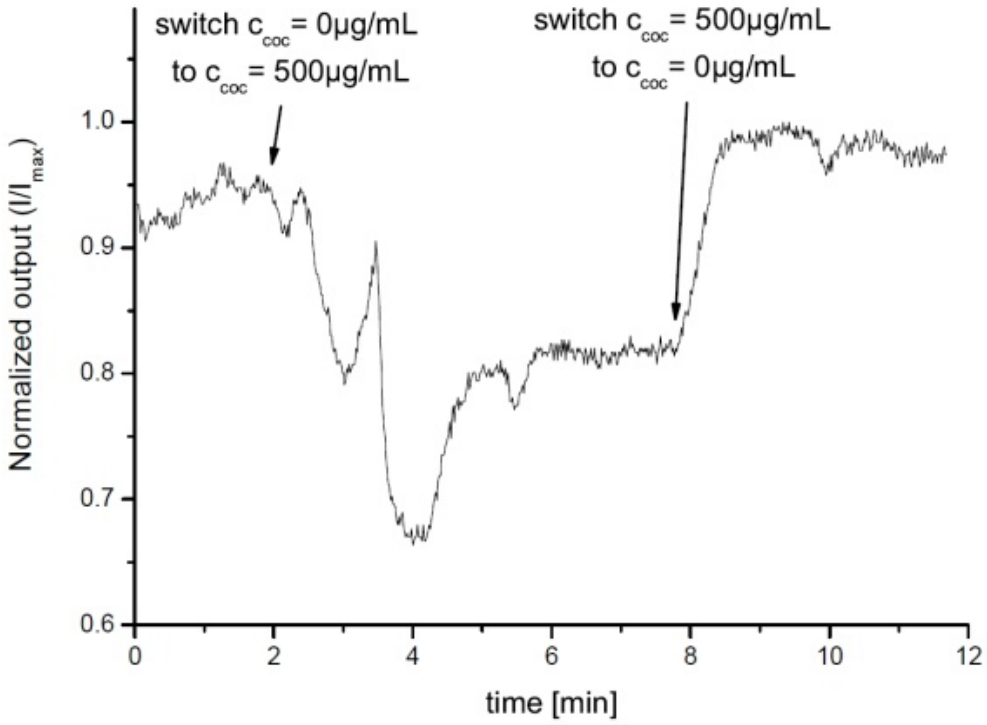




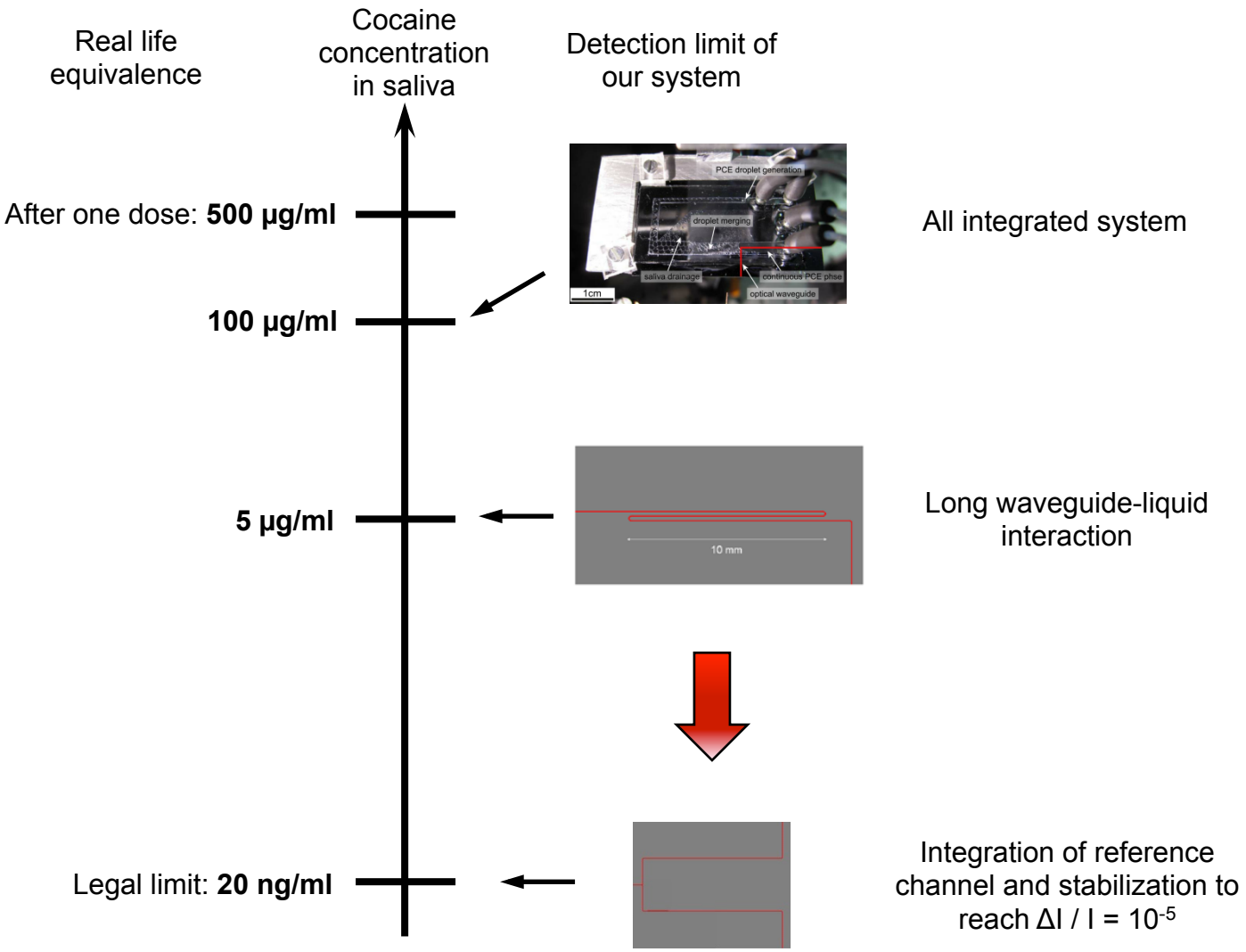
Measurements in liquids: all integrated system

Cocaine measurement in saliva using the all in one chip:



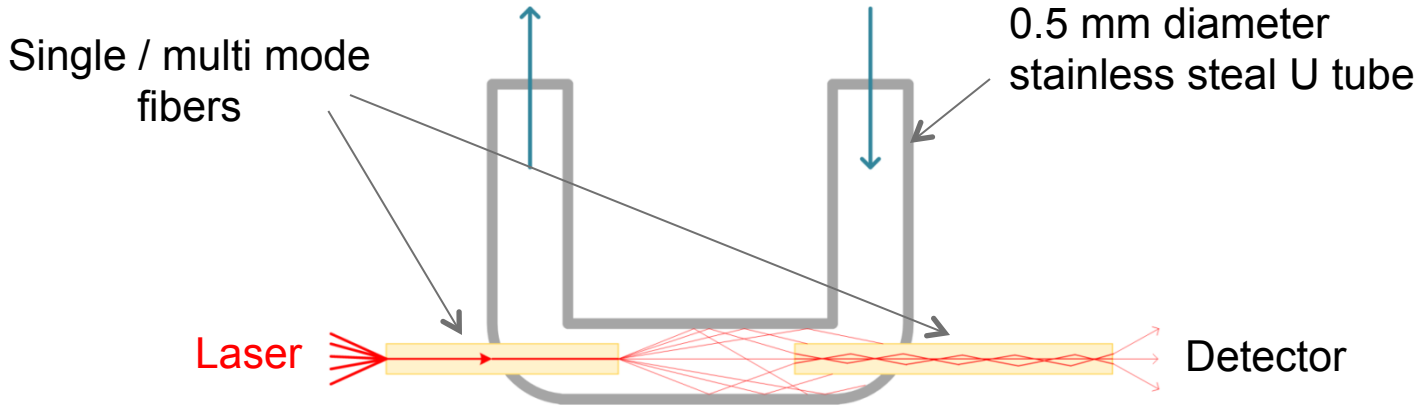


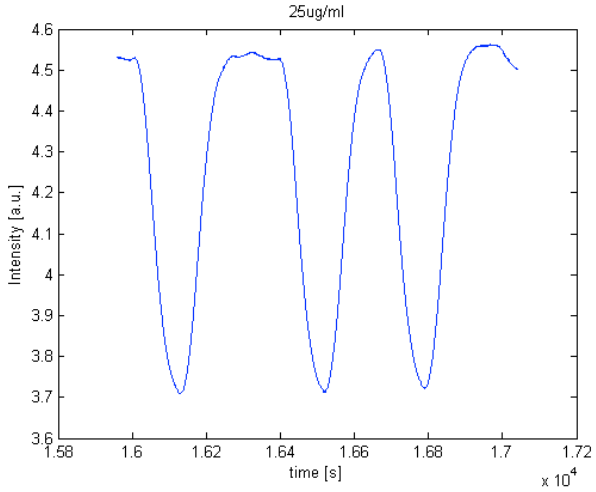
Measurements in liquids: status



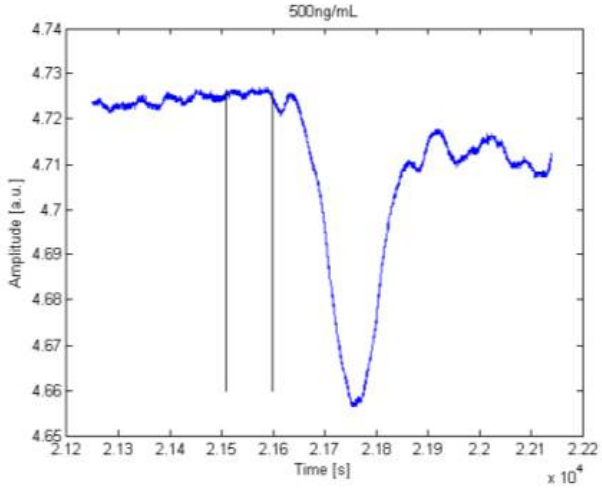
Fiber-based solution

Direct absorption in a tube with optical fibers:

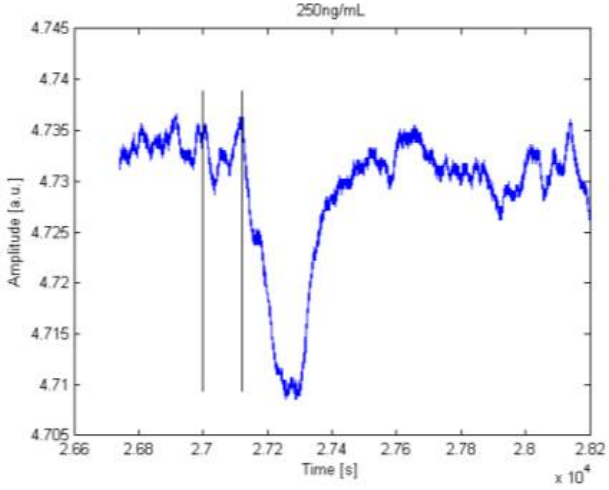




25 µg/mL

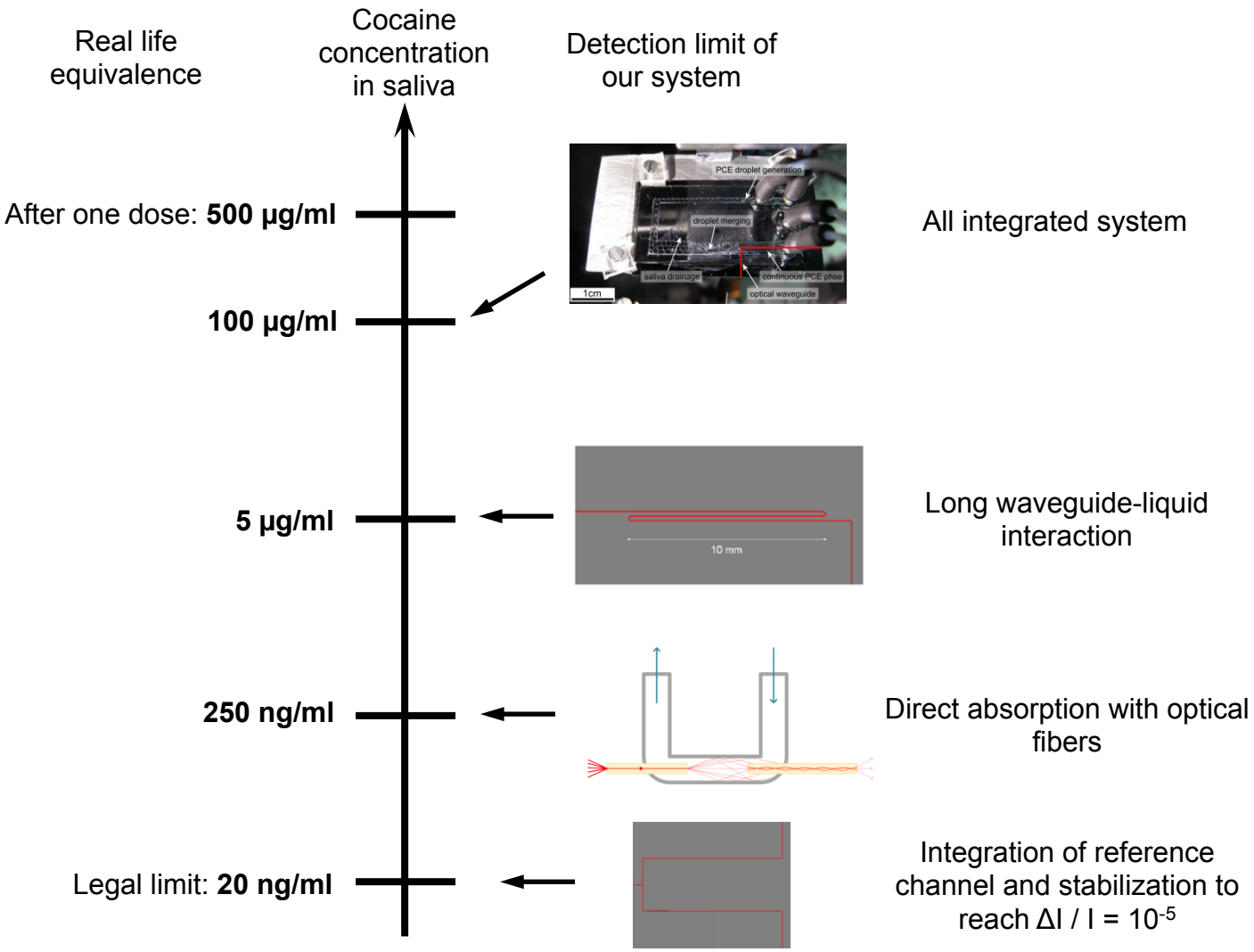


500 ng/mL

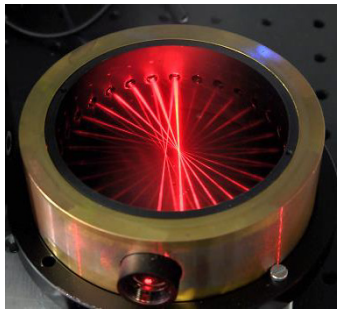


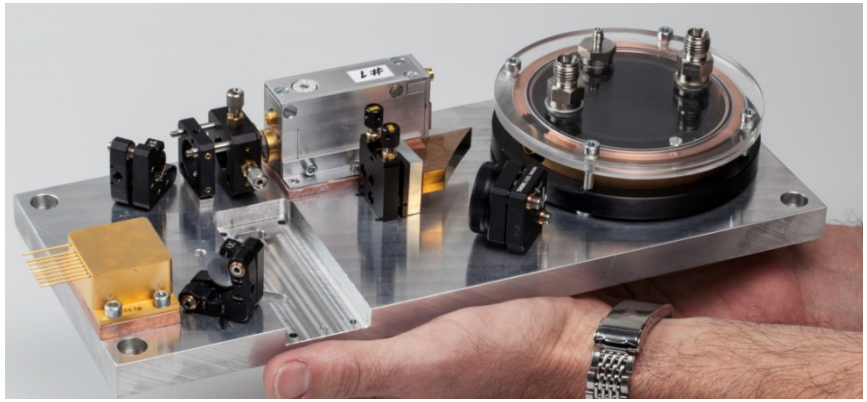
250 ng/mL

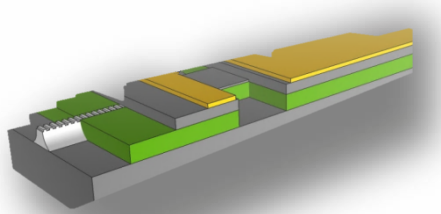
Measurements in liquids: status

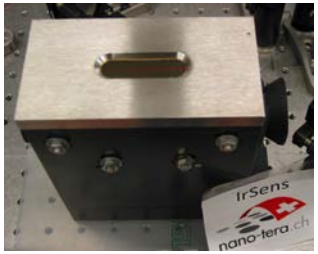


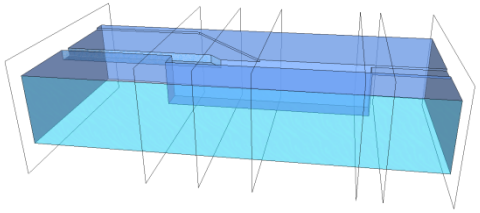
Conclusion

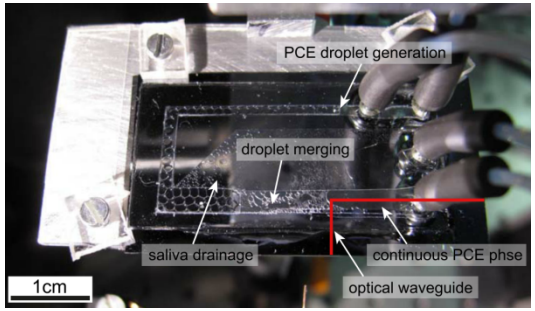


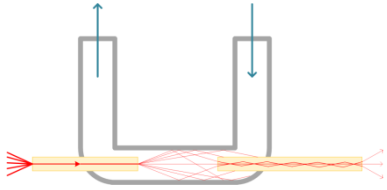












References:

- P. Jouy et al, "*Mid-infrared spectroscopy for gases and liquids based on quantum cascade technologies*", Analyst, in press (2014)

- www.qoe.ethz.ch

www.rsc.org/analyst **PAPER**

Mid-infrared spectroscopy for gases and liquids based on quantum cascade technologies

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