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Tunable Laser Absorption Spectroscopy

Laser
→ High-brightness and purely monochromatic light source

+ Tunable
→ Allows to precisely describe the absorption shape of the sample by scanning the laser wavelength

Absorption shape
+ Associated wavelength
→ Specific to a single chemical species

+ Intensity of the absorption
→ Quantification

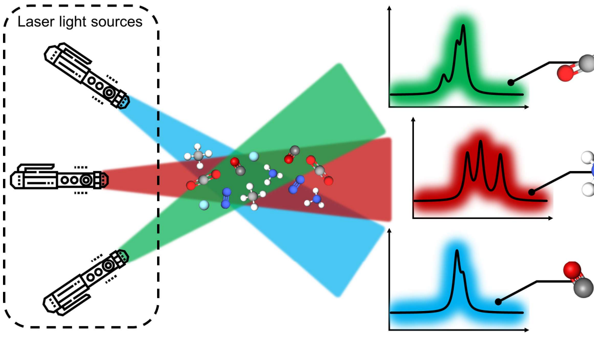
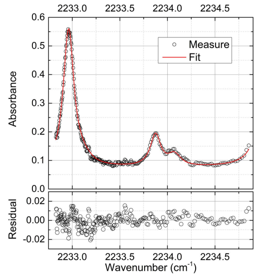


Illustration of the TLAS principle. Each color correspond to a distinct wavelength. Depending on the wavelength used, the observed absorption will not be the same, as represented by the projected-shadow like plot on the right. This allows to distinguish precisely the different chemical compounds.

Algorithm that match the acquired spectrum with known absorption pattern



Example of acquired absorption spectrum (circles) with associated fit (red solid line)

With associated residual

Absorption shape only rely on the chemical species
Intensity only rely on molecular concentration and interaction length
→ **Calibration free method**

Carbon Dioxide Optical Sensors

Mid-infrared sensor:
Light source : Quantum Cascade Laser

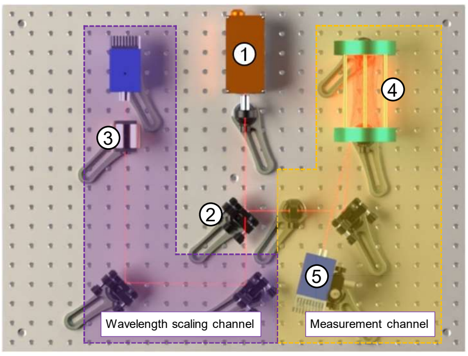
Intrapulse detection scheme
→ **Ultrafast measurement**
→ up to 10 000 measure per second

Measurement range : 10 ppm to 2%

Near-infrared sensor :
Light source: Antimonide Laser Diode

Conventional TLAS detection scheme
Up to 100 measure per second

Measurement range: 10 ppm to 2%



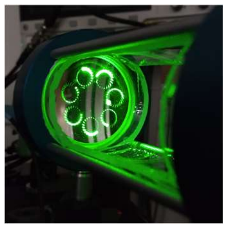
3D top view of a typical experimental setup

1: Laser source
2: Beam splitter
3: Fabry-Pérot etalon
4: Sampling cell
5: Infrared detector

Sampling Cell: **Dense Pattern Multipass Cell**

Air flow between two mirrors (distance = 15 cm)

Light make multiple reflections in the cell : Up to 200 pass
→ Increase the effective path length
→ **15 cm base-length × 200 pass = 30 m**



Multipass cell with visible alignment laser.
(Left: cell used with quantum cascade laser | Right: cell used with laser diode)

This type of sensor can be used to detect any chemical species with absorption features in the infrared. For example, the **lowest detectable absorption** of CO_2 with the mid-infrared sensor is **equivalent to an absorption of 3 ppb of NO_2.** It is just necessary to use **a laser source with a wavelength that matches the absorption of the target molecule**.

Outdoor campaign

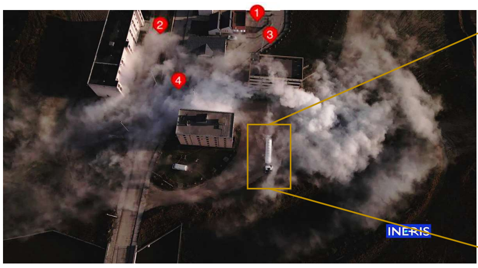
Deployed on field: invitation to a gas release trial at CENZUB
→ Centre d'entrainement aux actions en zone urbaine (Military training area, France)

Managed by the INERIS

Trial :

→ Several successive massive releases of CO_2 in a fake city with different kind of buildings

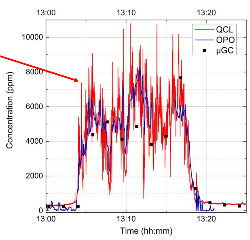
→ Various sensor technologies placed at different spots to study the gas dispersion



Top view photo of trial site. The numbered red pins indicate the positions of the sensors during the successive trial

Picture of the gas source during a release

Picture of the quantum cascade laser sensor deployed on the trial site. The instrumental setup is shown in the box above the rolling cart. The yellow/black pole is the sampling point for the gas chromatograph for comparison



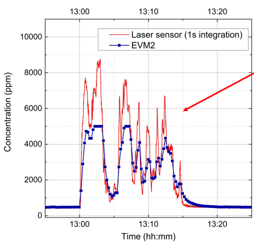
Comparison with reference instrument :
NDIR Sensor & Gas Chromatograph

→ Good agreement with other measurement systems

→ **Higher measurement range**
→ **Higher acquisition rate**
→ **Higher temporal resolution**
→ Allows the study of high-speed phenomena

Fully qualified sensors to be deployed

Picture of the laser diode sensor deployed on the trial site. The instrumental setup is enclosed in the box above the rolling cart. The device above the box is an NDIR sensor (ULCO, Dunkerque) for comparison



Perspectives

→ Improve the limits of detection
→ Dedicated driving and acquisition electronics
→ Lighter and more compact device: Sampling volume down to tens cm^3 (Under development)
→ **Application on other gas**: N_2O, CH_4, NO_2, …

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The work on the QCL sensor has been published in a scientific journal.
Scan the QR code to access to the journal page.