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Can Science Save the Earth? –
Optical TDLAS technique

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IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

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TDLAS Technique

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Advantages of TDLAS technique

- Non invasive monitoring;
- Gas in scattering media sensing;
- Sensing with back-scattering targets;
- Pressure measurement techniques for weak absorption signals;
- Time resolved, dynamic sensing;
- Temperature measurement through absorption spectroscopy
- ability to achieve very low detection limits (of the order of ppb)
- Stable e well proved technique

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Absorption spectroscopy

- Absorption spectroscopy is a generic term to describe every measurement technique based on the phenomenon of absorption of radiation as a function of wavelength caused by interaction with the sample.

- The intensity of this absorption varies with wavelength because energy transitions between radiation and matter can more likely happen between two well defined quantum mechanical states of the sample. This model yields to a structure of different absorption lines (spectrum) which is a fingerprint of the material

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TDLAS setup

- tunable diode laser light source
- transmitting (i.e. beam shaping) optics
- optically accessible absorbing medium
- receiving optics
- Detector

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How TDLAS works

The emission wavelength of the tunable diode laser is tuned over the characteristic absorption lines of a species in the gas in the path of the laser beam.

This causes a reduction of the measured signal intensity due to absorption, which can be detected by a photodiode, and then used to determine the gas concentration and other properties

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Different tunable lasers

I) Used laser is based on the application and the range over which tuning is to be performed

- InGaAsP/InP laser (tunable over 900 nm to 1.6 μm)
- InGaAsP/InAsP (tunable over 1.6 μm to 2.2 μm)
- Typical laser linewidth is of the order of 10−3 cm−1 or smaller

I) Laser tuning by either adjusting their temperature or by changing injection current

- T changes allow tuning over 100 cm−1, limited by slow tuning rates (a few hertz)

- I changes can provide tuning at rates as high as ~10 GHz, but it is restricted to a smaller range (about 1 to 2 cm−1

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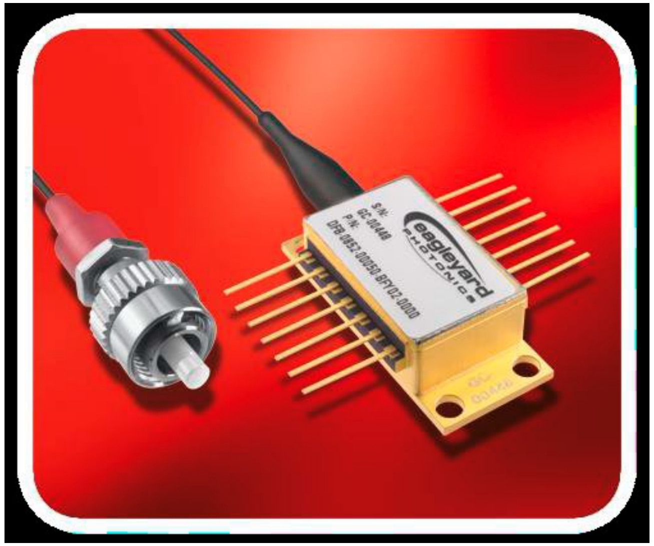
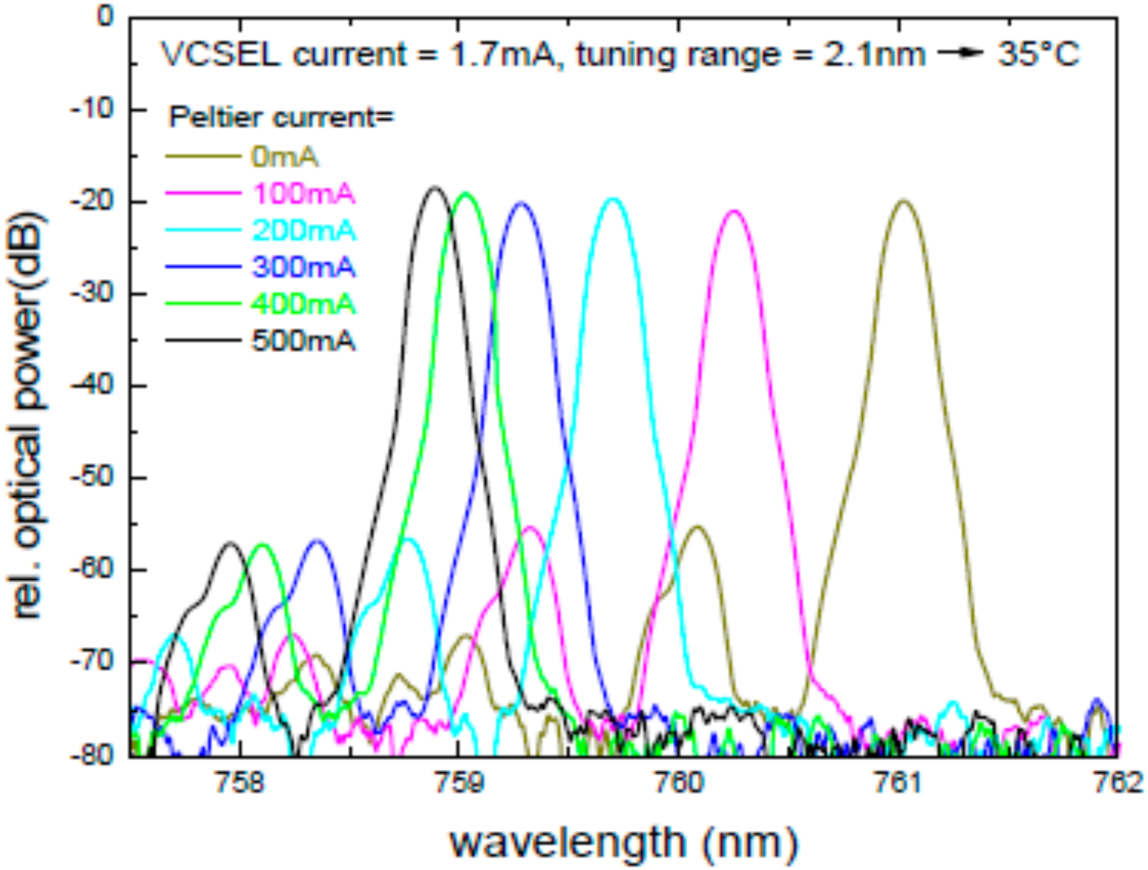
Different tunable lasers

A fiber pigtailed DFB laser. The butterfly casing is very common in the telecommunications environment, usually provided with built in TEC element, temperature sensing thermistor and reference photodiode





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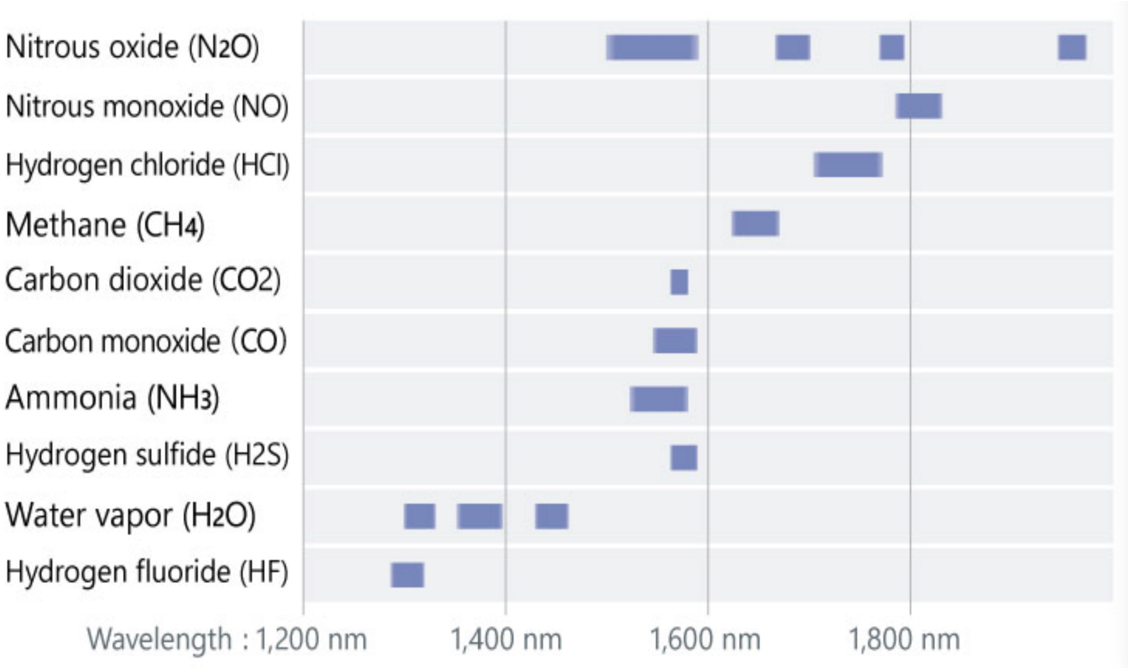
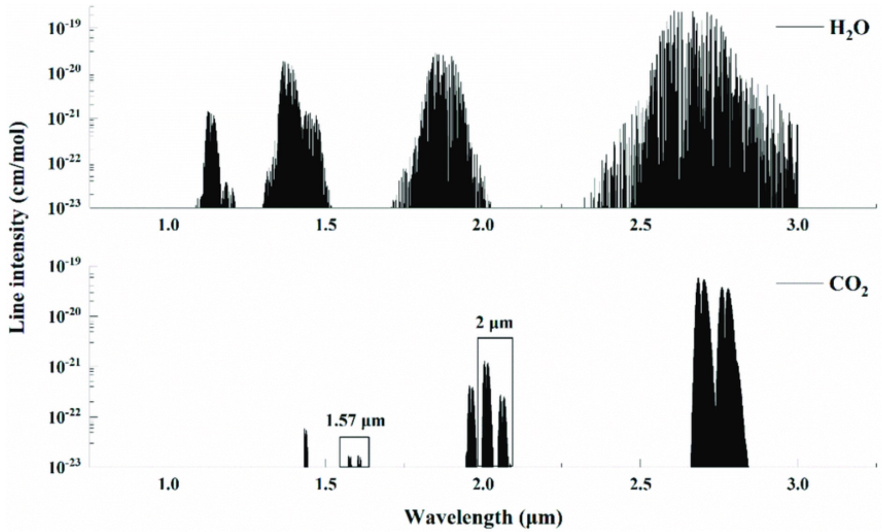
Spectral absorption of gases





The absorption spectrum of CO 2 and H 2 O between 1.0 μm and 3.0 μm.

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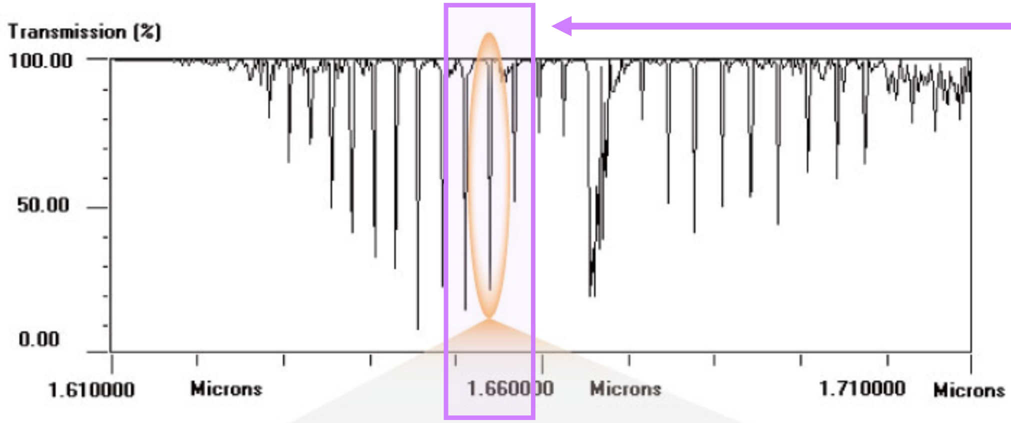
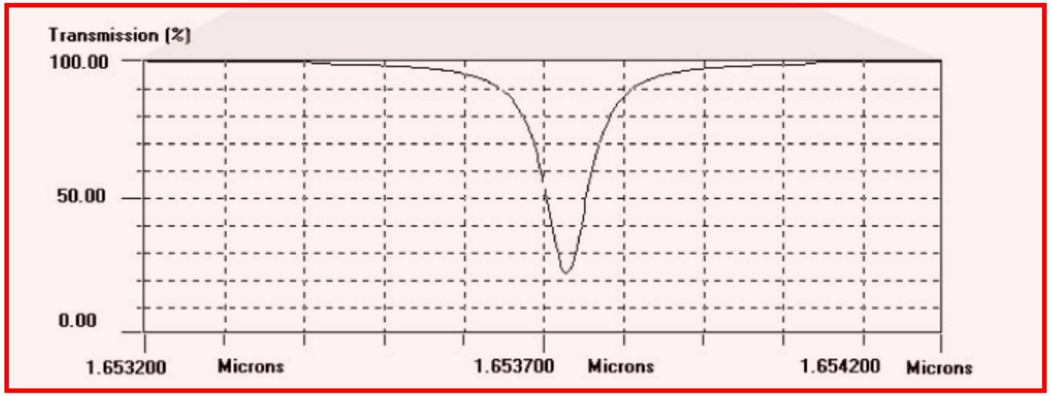
T vs I response of tunable laser diodes



T laser from 0°C to 40°C



I laser from 20 mA to 200 mA

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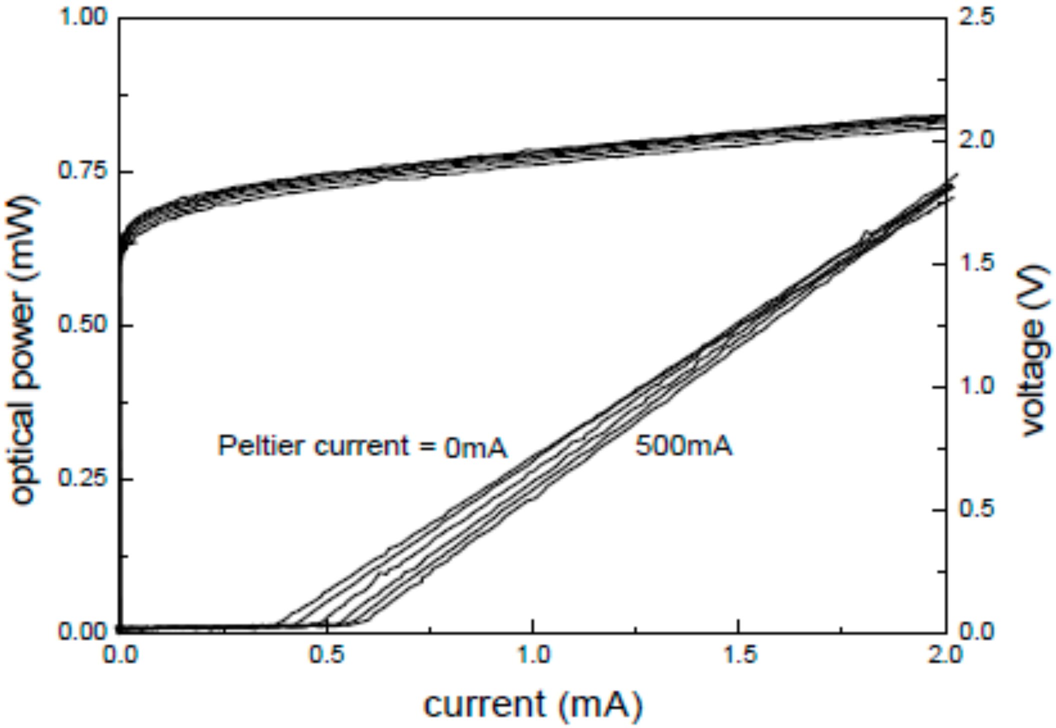
Different tunable lasers

Optical response of tunable laser to changes of current / voltage



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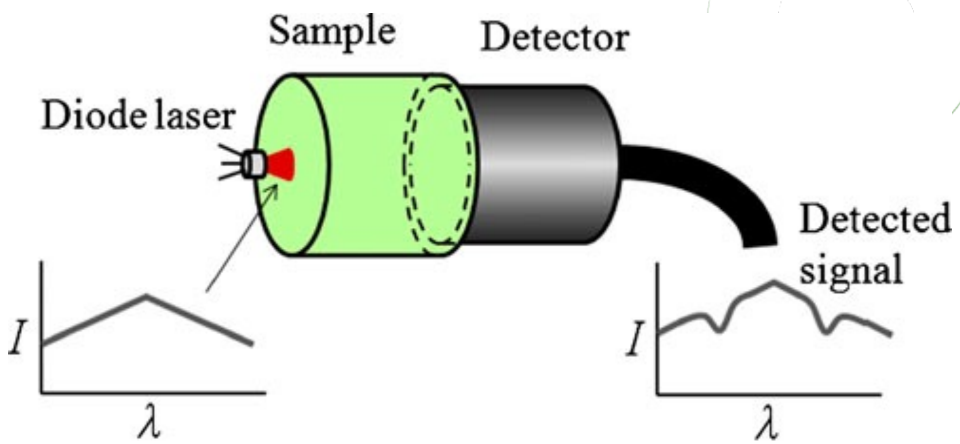
Direct-absorption spectroscopy

Beer-Lambert law   Transmittance T is given by $T = I / I_0 = \exp(-\sigma \, l \, N)$



Nomenclature: I – Intensity (a.u.), λ – Wavelength (nm)

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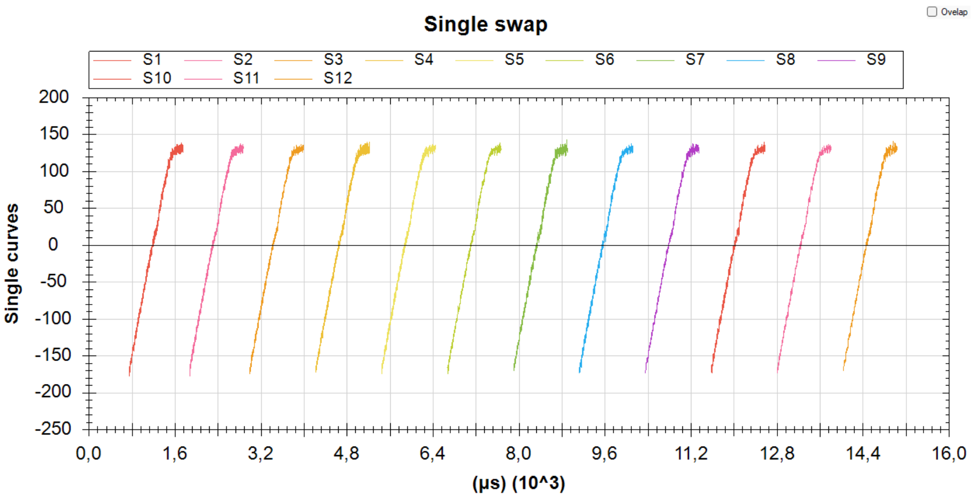
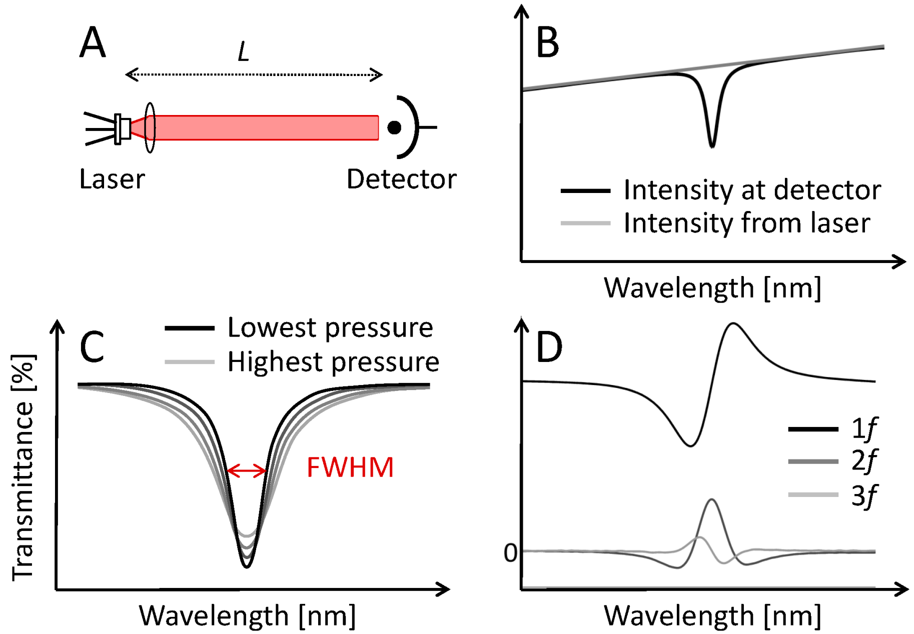
WMS (Wavelength Modulation Spectroscopy)

technique used to overcomethe traditional problems of Direct-absorption spectroscopy when investigating low absorbances, where there is a need to resolve a tiny absorption feature over an intense source signal





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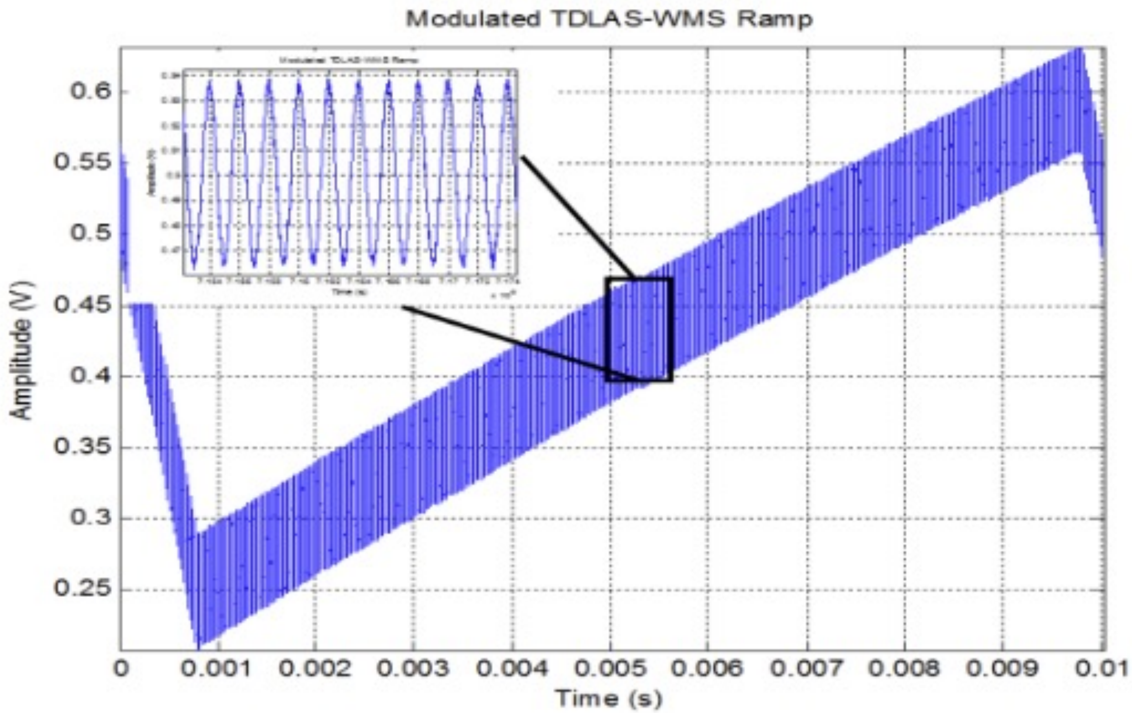
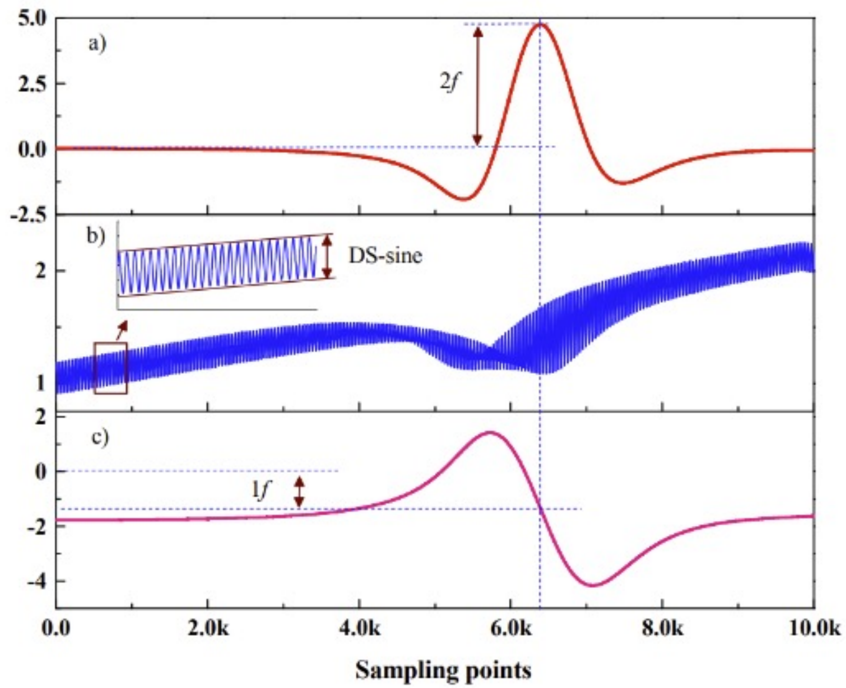
TDLAS Technique

WMS (Wavelength Modulation Spectroscopy)

Modulating and demodulating the signal at higher frequency than the used one



1f and 2f harmonics



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Application of TDLAS technique for the GreenHouse Gases

- Detailed greenhouse gas (GHG) emission estimation requires extensive atmospheric concentration measurements of regions with high GHG emissions (cities, airports, power plants …..)
- Calculation of the emissions from these specific locations has large uncertainties due to insufficient emission monitoring
- The installation and operation of ground-based stations are considered an optimal solution for detecting and monitoring GHG concentrations
- Robust, reliable, easy-to-maintain, remotely-operated instruments detecting GHG in the atmosphere are essential to survey GHG concentrations in the atmosphere from places with high emissions
- These instruments must have low detection limits and high accuracies to measure global variations of GHG concentrations. In particular, their accuracy must be in the range of sub-ppm for carbon dioxide (CO_2) detection and a few ppb for methane (CH_4) detection.

where,

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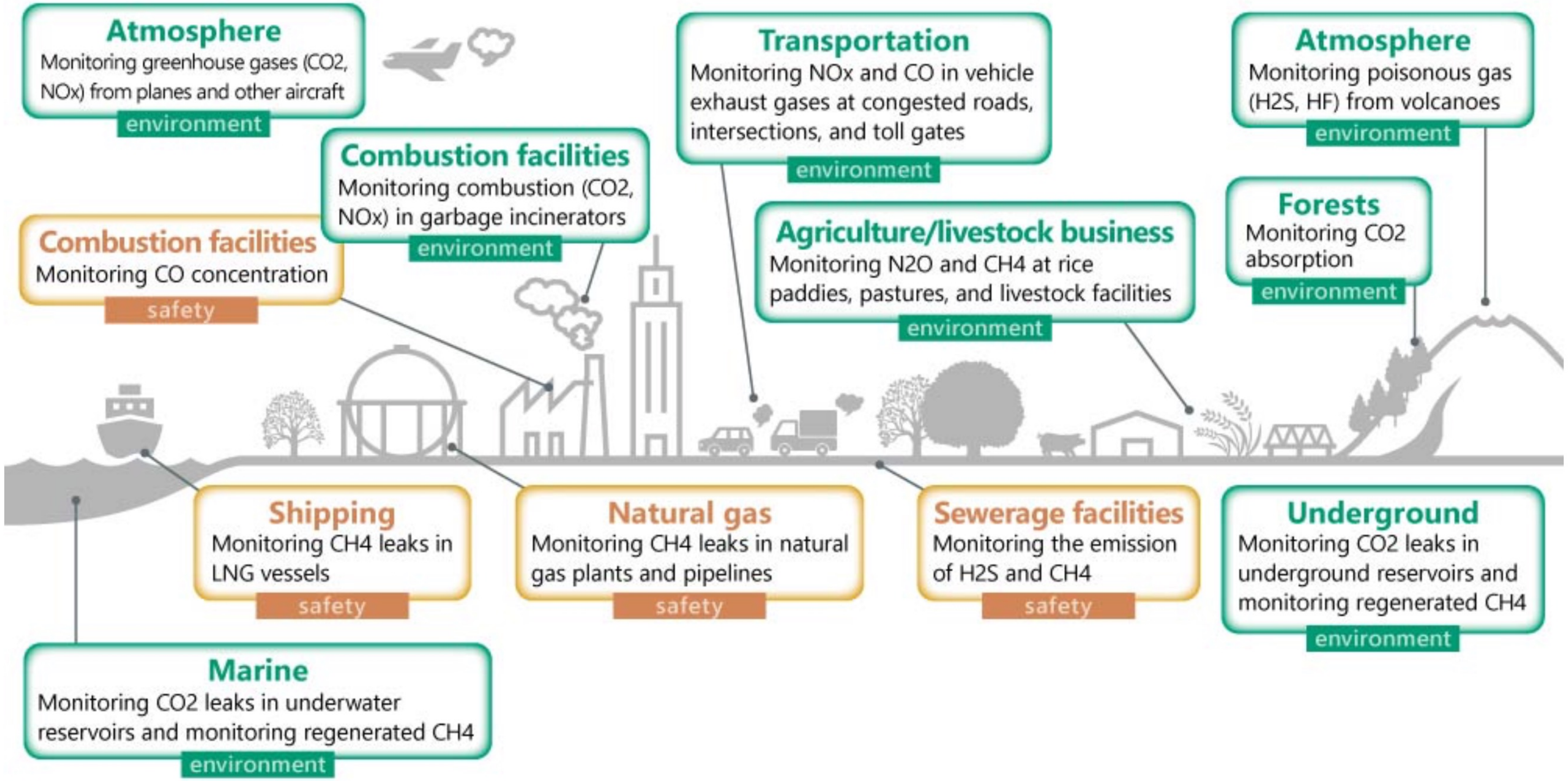
Gas Sensing for Various Applications



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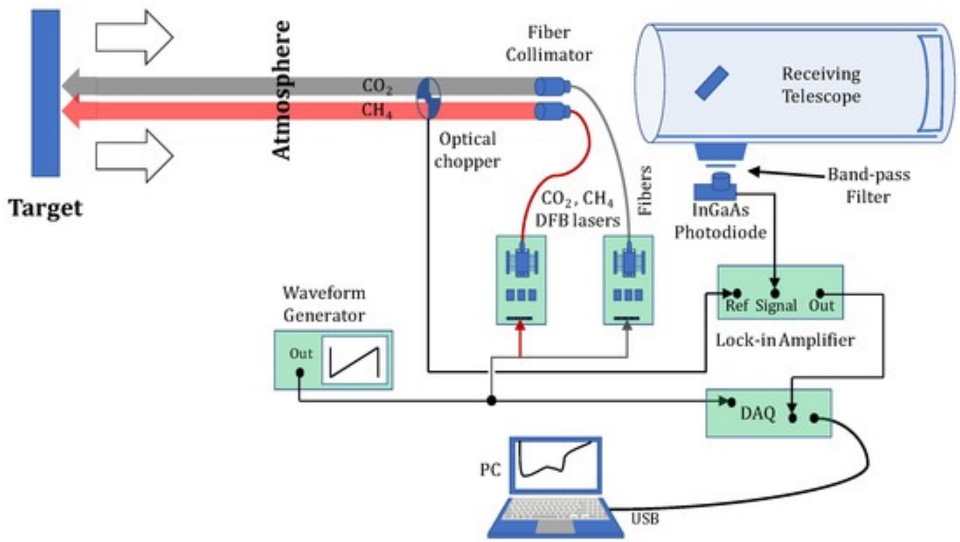
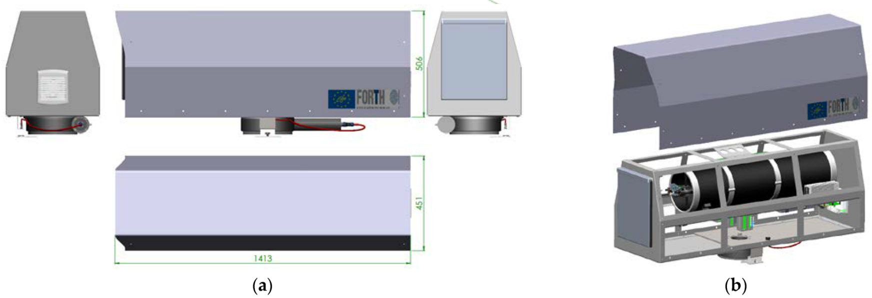
GHG detection by open paths TDLAS spectroscopy

Open-path TDLAS is a flexible, cost-effective sensing technology for measuring selected target gases in complex mixtures associated with evolving modern industrial applications

The instrument detects the back reflection of the laser beam from any topographic target.





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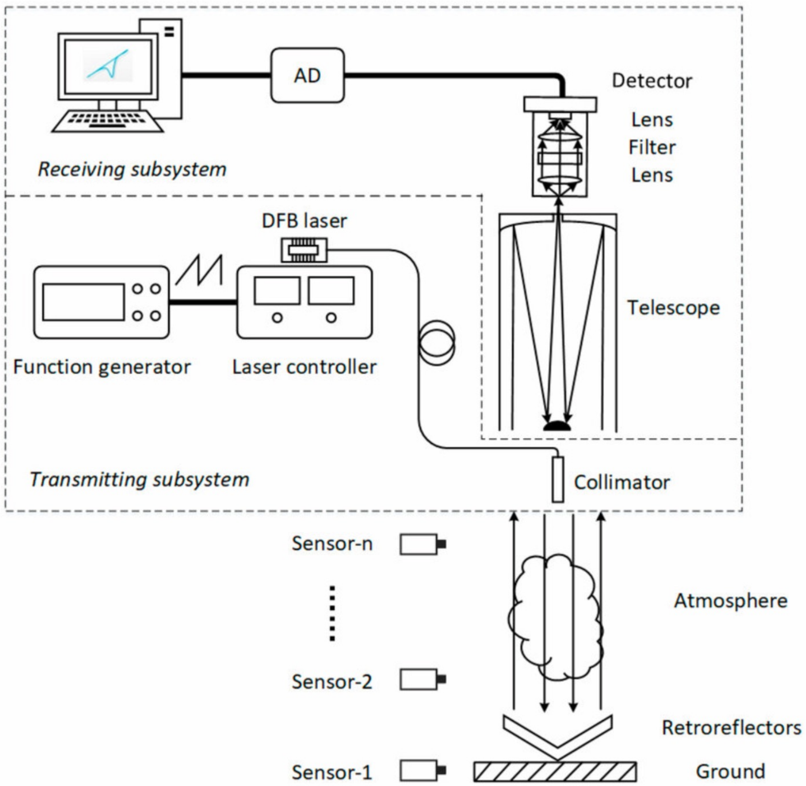
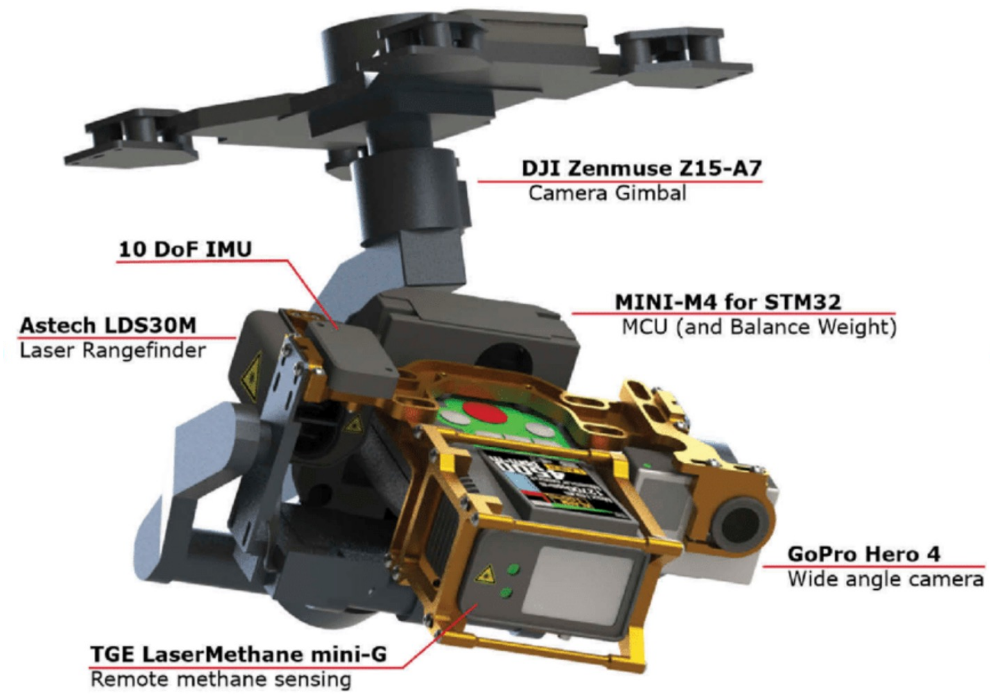
Airborne/Satellite applications of TDLAS technique



Schematic diagram of the open-path tunable diode laser absorption spectroscopy (TDLAS) system for measuring atmospheric CO 2 column concentration.



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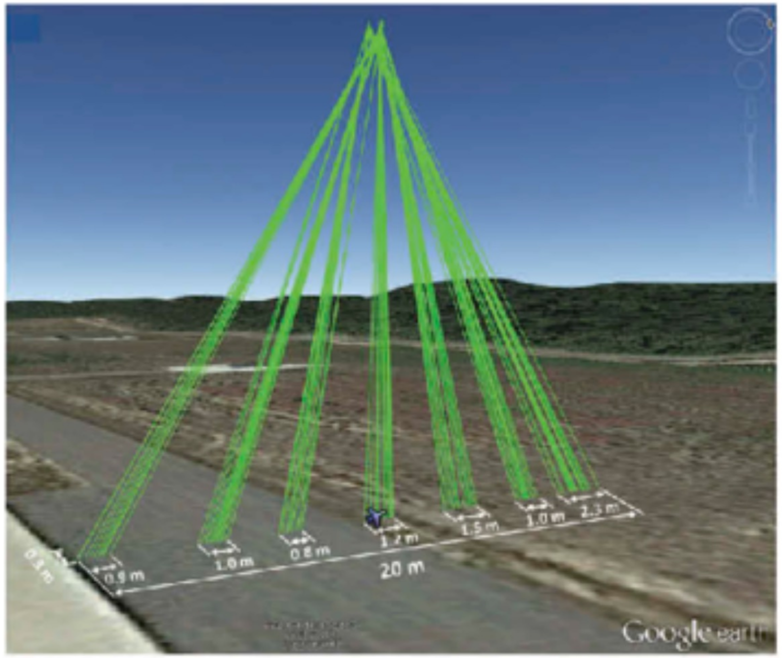
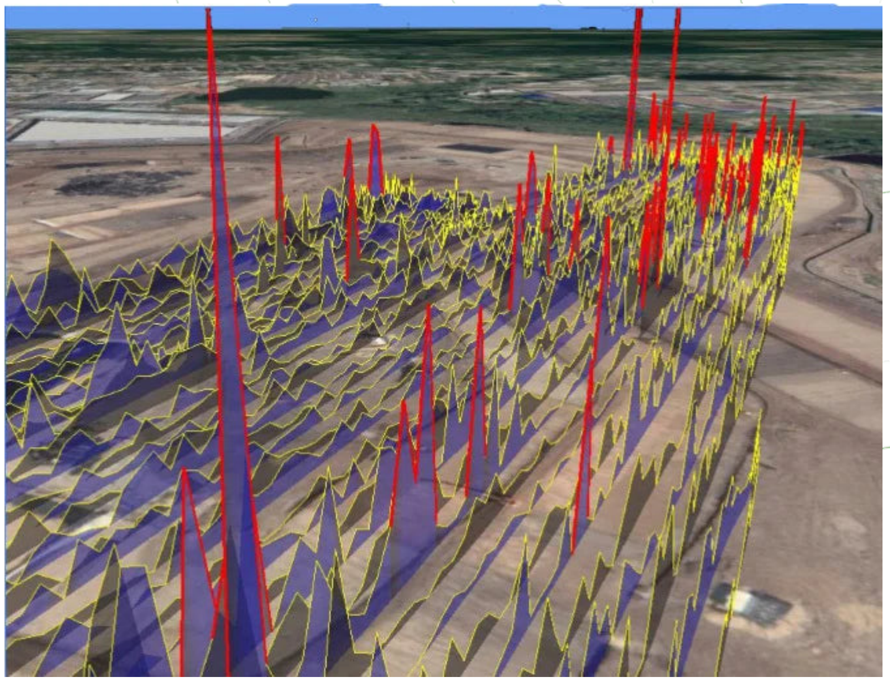
Airborne/Satellite applications of TDLAS technique





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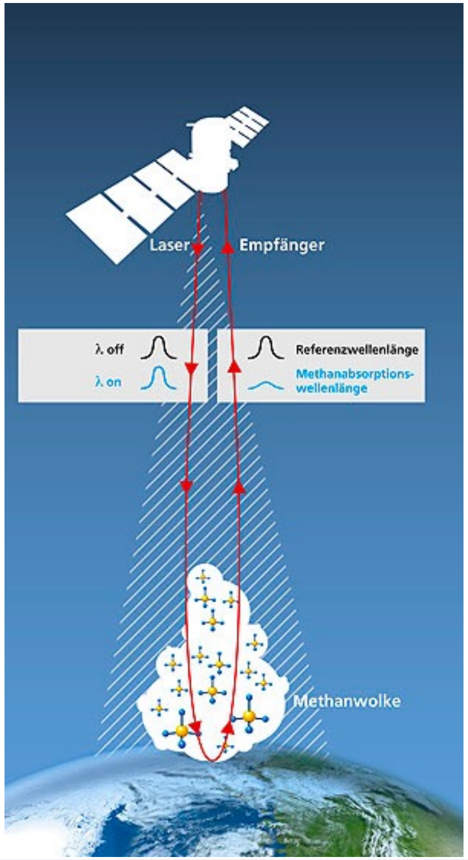
CUBESat applications of TDLAS technique



For future CUBESat applications further important technological improvements are requested:

- Larger light receivers
- High power tunable laser diodes (now P < 200 mW)
- High sensitivity/low noise IR sensor at $\lambda > 1.5$ um

where,

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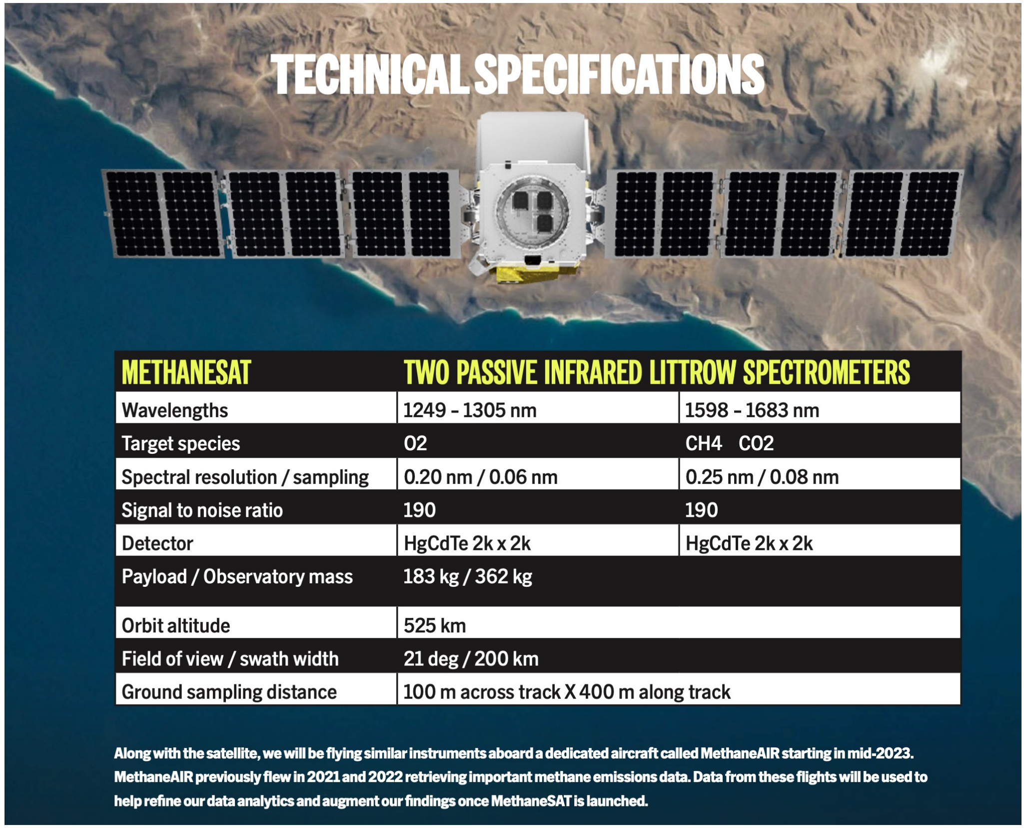
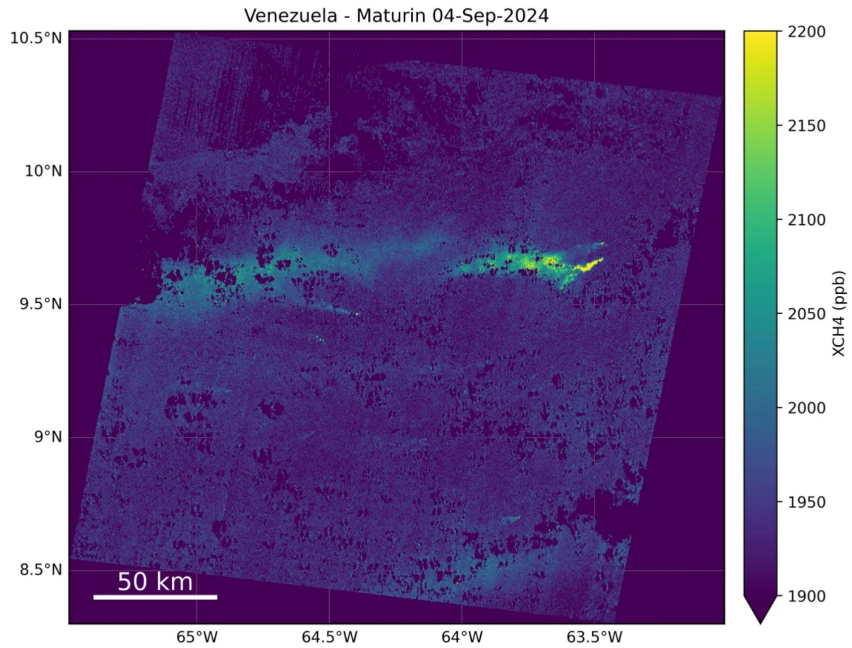
Satellite methane detection by spectrometer



METHANESAT	TWO PASSIVE INFRARED LITTROW SPECTROMETERS	
Wavelengths	1249 - 1305 nm	1598 - 1683 nm
Target species	O2	CH4 CO2
Spectral resolution / sampling	0.20 nm / 0.06 nm	0.25 nm / 0.08 nm
Signal to noise ratio	190	190
Detector	HgCdTe 2k x 2k	HgCdTe 2k x 2k
Payload / Observatory mass	183 kg / 362 kg	
Orbit altitude	525 km	
Field of view / swath width	21 deg / 200 km	
Ground sampling distance	100 m across track X 400 m along track	



An image showing methane being vented into the atmosphere in Venezuela. MethaneSAT

THANKS!

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