GASERA

PA101
PHOTOACOUSTIC
DETECTOR

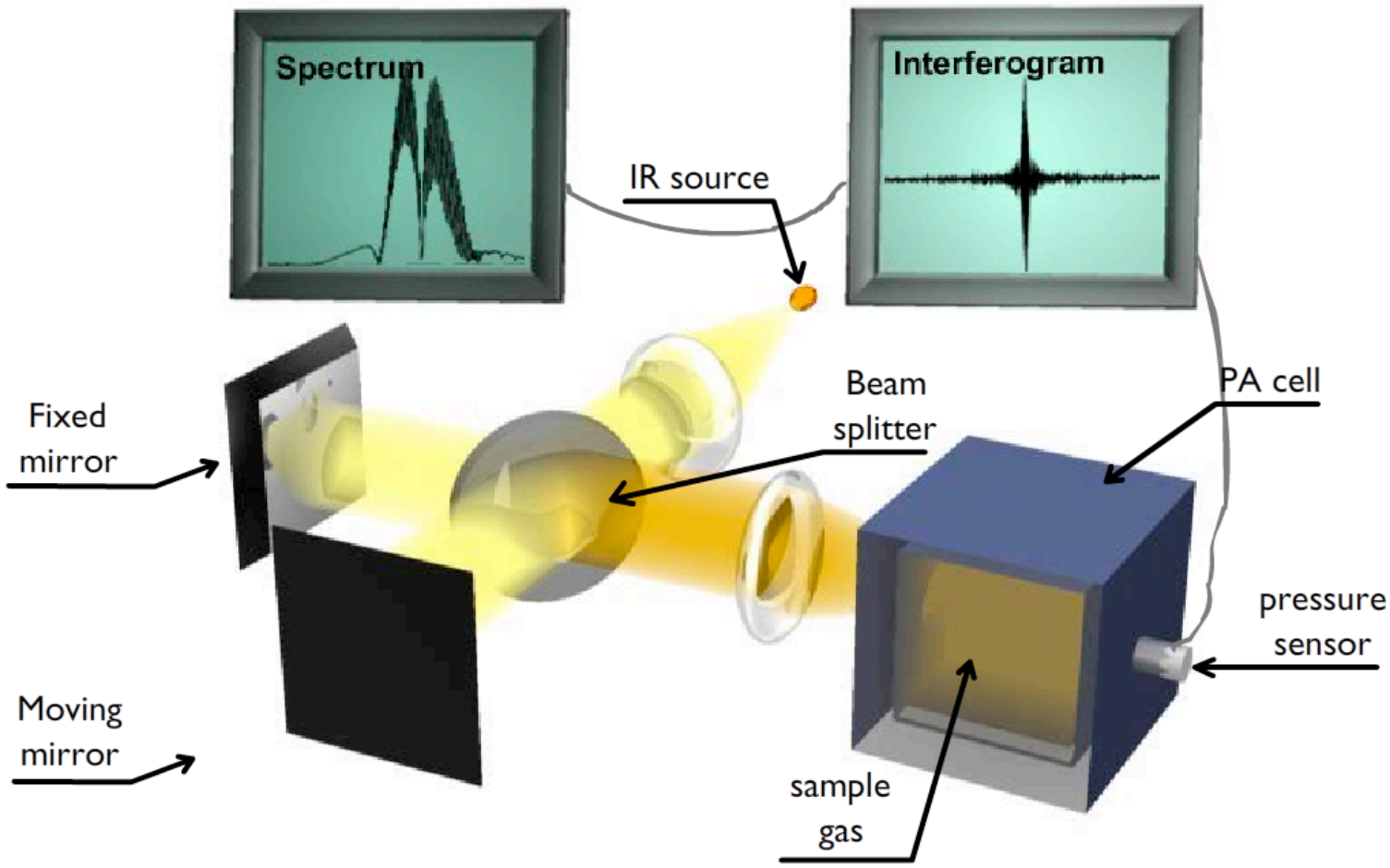
FTIR accessory: PA101

Photoacoustic
gas analysis module

Key features

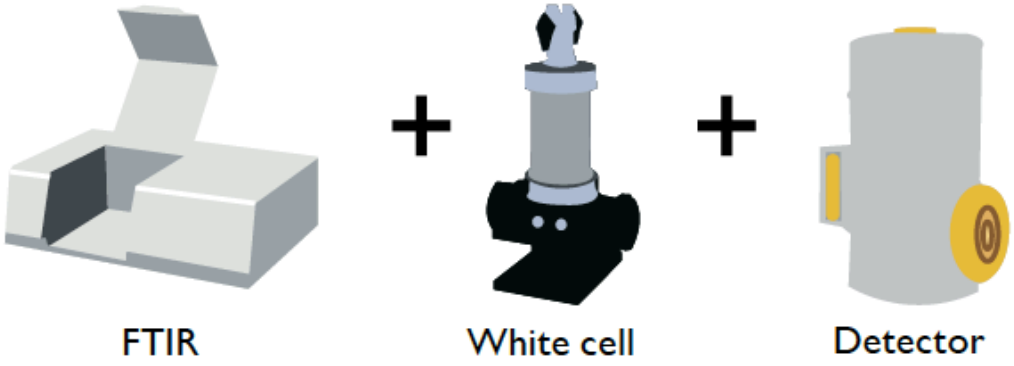
- Photoacoustic gas analysis module for laboratory FTIRs
- Includes sensitive photoacoustic cell with ultra sensitive patented cantilever enhanced optical microphone
- Includes a user programmable gas exchange unit
- Optical path length: 8 cm
- Total internal gas volume: 30 ml
- Fits all major FTIR instruments

FTIR-PAS setup



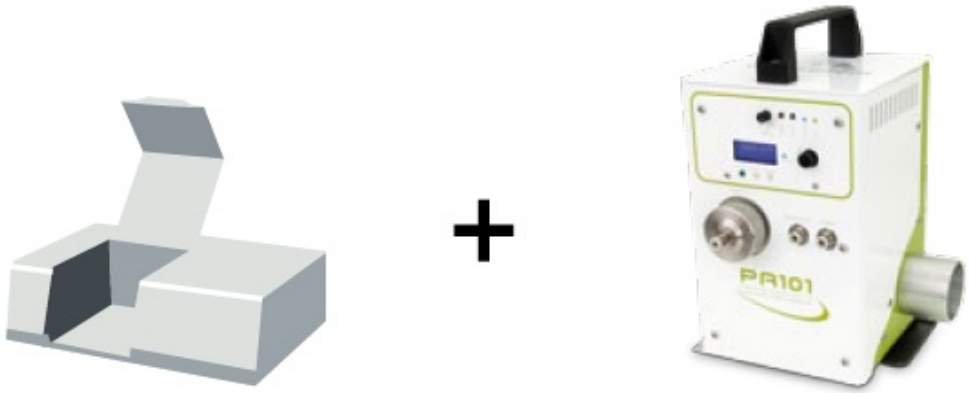
PA101 replaces the conventional long path gas cell and the IR detector

Conventional FTIR gas measurement



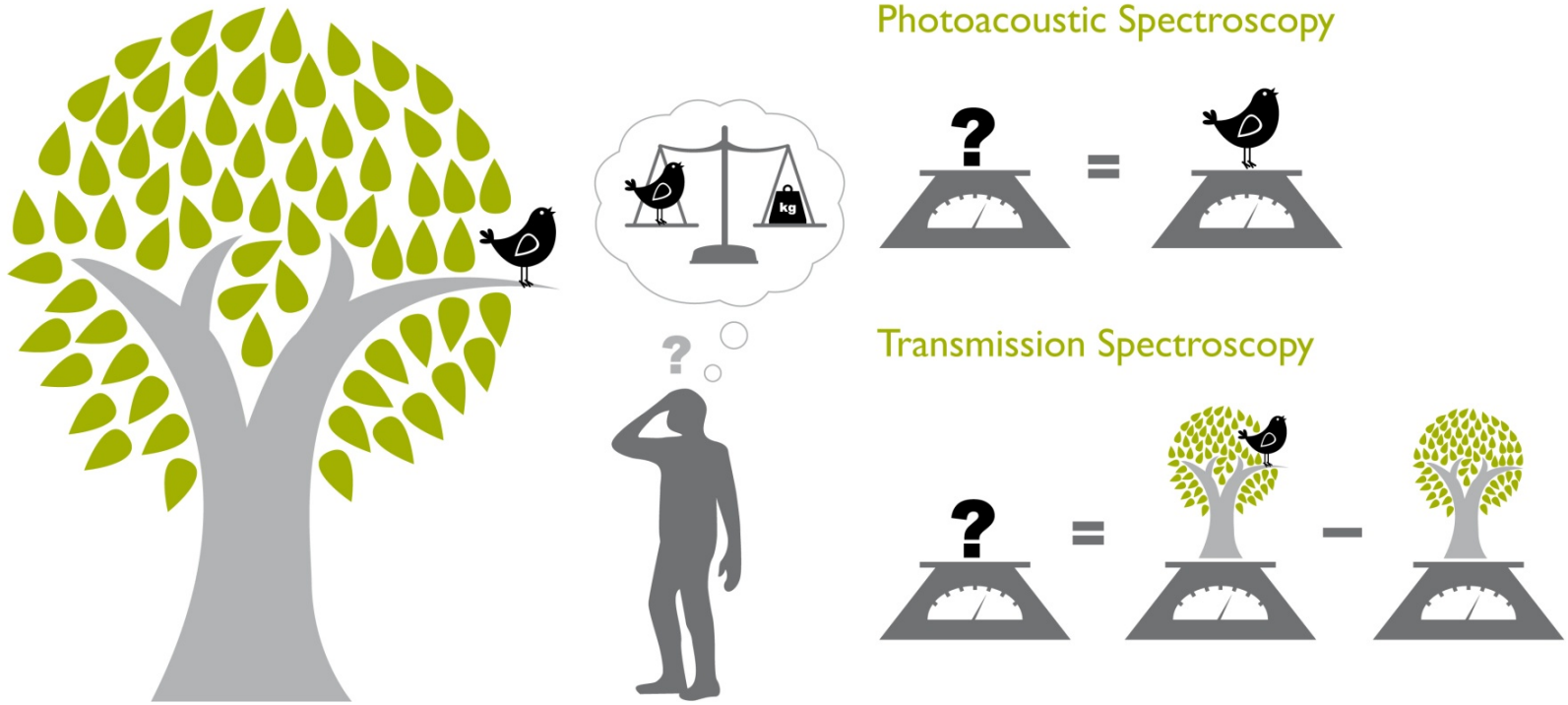
- Large gas volume
- Non-linear
- Limited dynamic range
- Frequent background measurement

PA101 photoacoustic gas analysis setup



- Low gas volume
- Highly linear
- Wide dynamic range
- Background measurement once

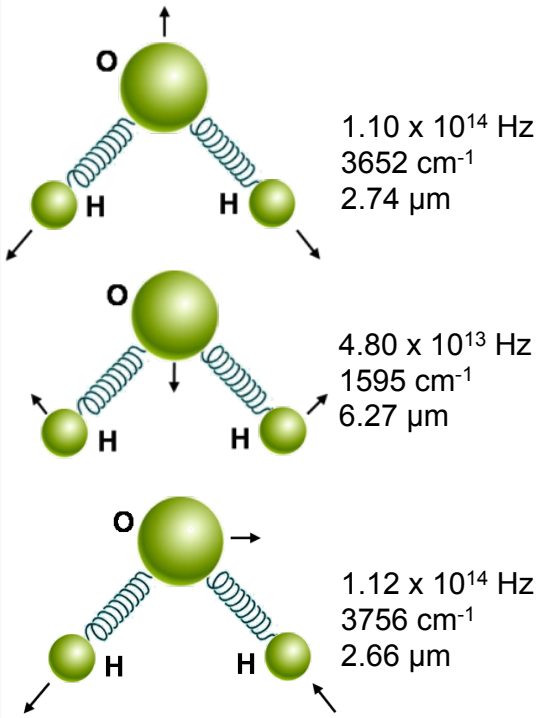
Direct measurement in PAS vs. Transmission spectroscopy



The **absorption is measured directly** in PAS, which makes the measurement very accurate and **free of drift**. This is the key factor for the unbeatable **stability and reliability** of the PAS method. In transmission spectroscopy the small decrease of the large signal is measured, and therefore, small changes in the background signal create large errors and drifts in the measurement result.

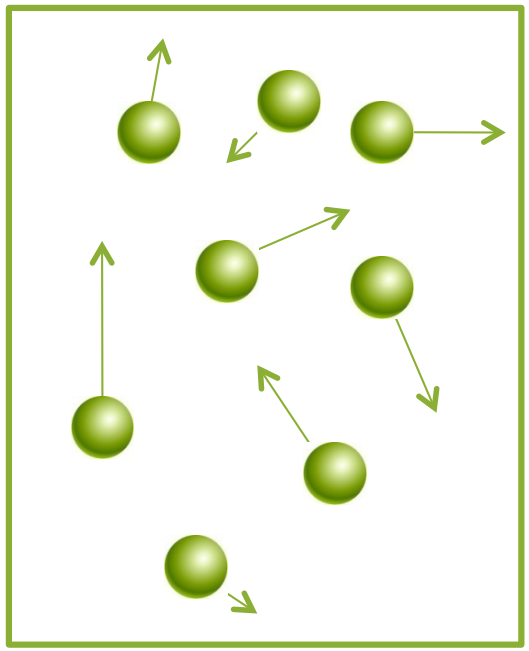
Molecular vibrations

H_2O molecule vibration modes and resonance frequencies



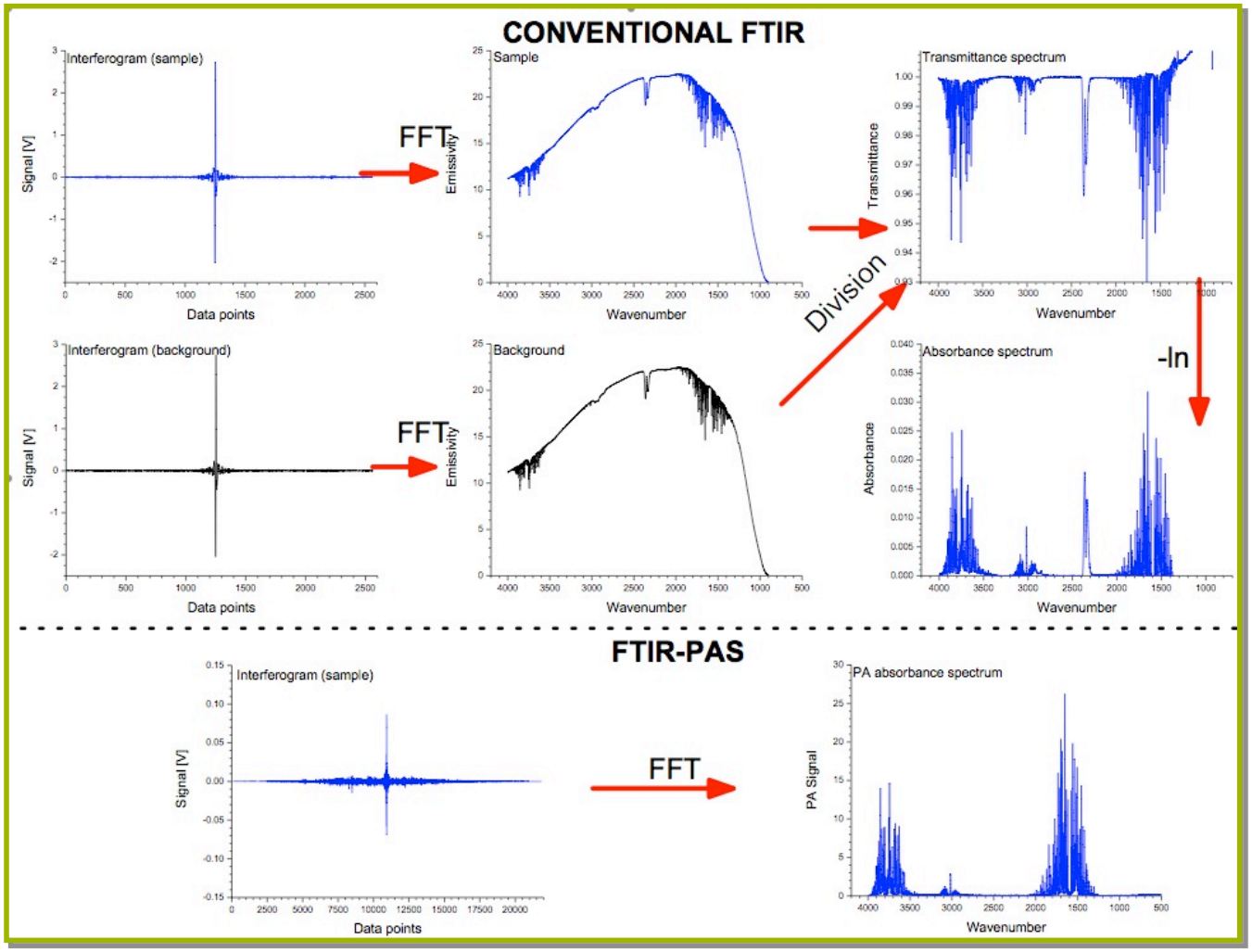
- Signal is generated by infrared absorption into the different molecular vibrations in the PAS.
- Molecules do not only move with a high speed, but they also rotate and vibrate.
- Different molecules have different vibrational frequencies depending on the shape of the molecule, the forces between the atoms and the mass of its atoms.
- Single molecule can have several different vibration modes.
- Vibrations are able to absorb infrared radiation, which has the same wavelengths as the vibrations.
- Increased vibration leads to faster movement in the molecular collisions and the temperature is raised in the absorption.

Gas temperature and pressure



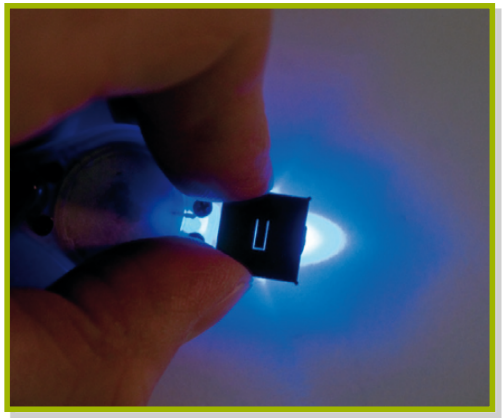
- Heating of the gas increases the temperature and the pressure in the photoacoustic cell.
- Gas is a collection of molecules that are in a continuous random motion. They are constantly colliding to each other and also to the surrounding walls.
- One liter of gas contains 3 x 10^{22} molecules (NTP).
- The absolute temperature of the gas is proportional to the kinetic energy (i.e. to the square of the velocity) of gas molecules. At 20°C temperature the average velocity of gas molecules is 407 m/s. At 40°C the it is 421 m/s.
- The bombardment of the molecules to the sensor element creates a pressure, which rises along with the temperature. E.g. at 20 °C the molecules create the pressure of 1.013 x 10^5 N/m^2 in the photoacoustic cell and after heating to 40 °C the pressure is 1.08 x 10^5 N/m^2.

FTIR-PAS principle

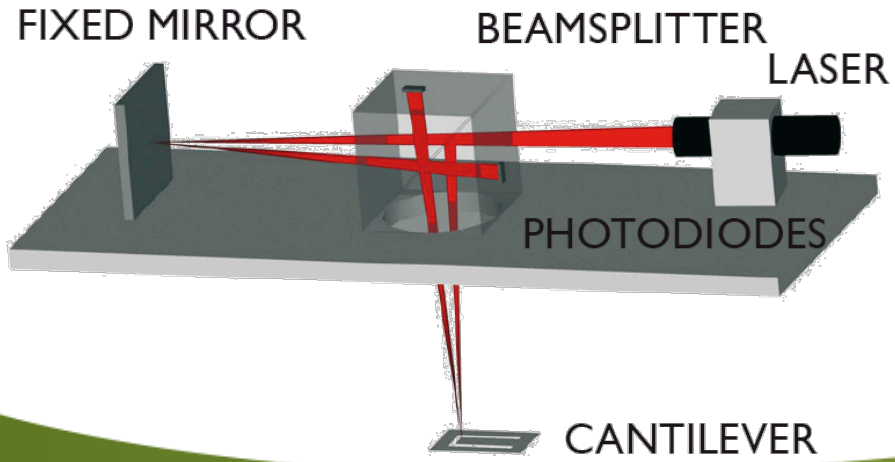


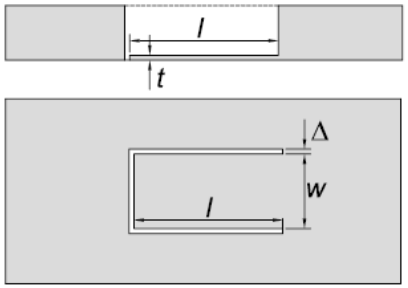
- In FTIR-PAS the sample cell and the IR detector are replaced with the photoacoustic gas cell
- Only the absorbed part of the radiation produces PA signal – no gas, no signal i.e. zero background
- Only one recorded interferogram has to be transformed to get an infrared spectrum of the sample gas

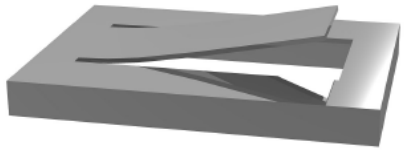
Cantilever enhanced optical microphone



- Cantilever pressure sensor provides high sensitivity to small pressure variations.
- The movement of the cantilever is measured with a laser readout interferometer.
- The microphone has highly linear response over a very wide dynamic range.
- The response of the cantilever remains stabile, even if the ambient temperature is varied.
- Performance: Sensitivity: ~10V/Pa, noise level: minimum detectable pressure variation in the PA101 cell: ~5 x 10^{-7} Pa/√Hz (RMS)







Performance

Sample: **CH4 1000ppm**

Measurement time: **60 s**

FTIR device: Thermo Antaris IGS

Resolution: 8 cm^{-1}

HeNe laser frequency: 2.5 kHz

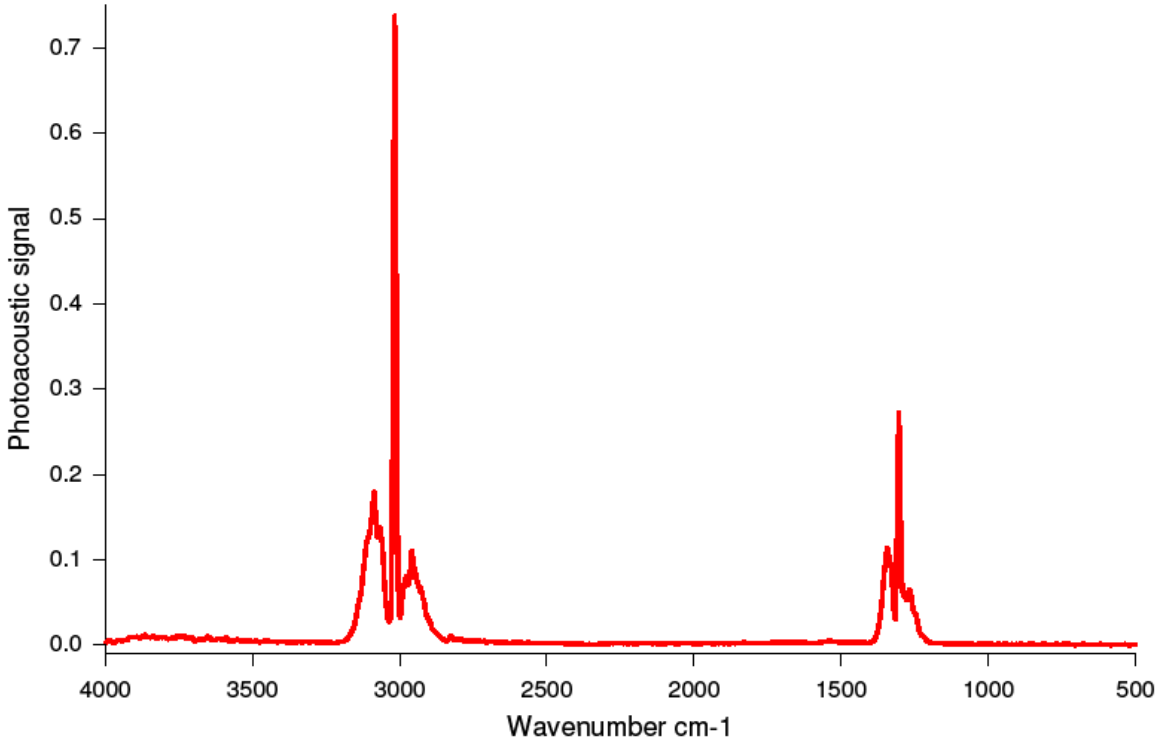
Pressure: 1 atm

Max signal@3017: 221

Noise(2200-2100 cm-1) : 0.081 peak-to-peak

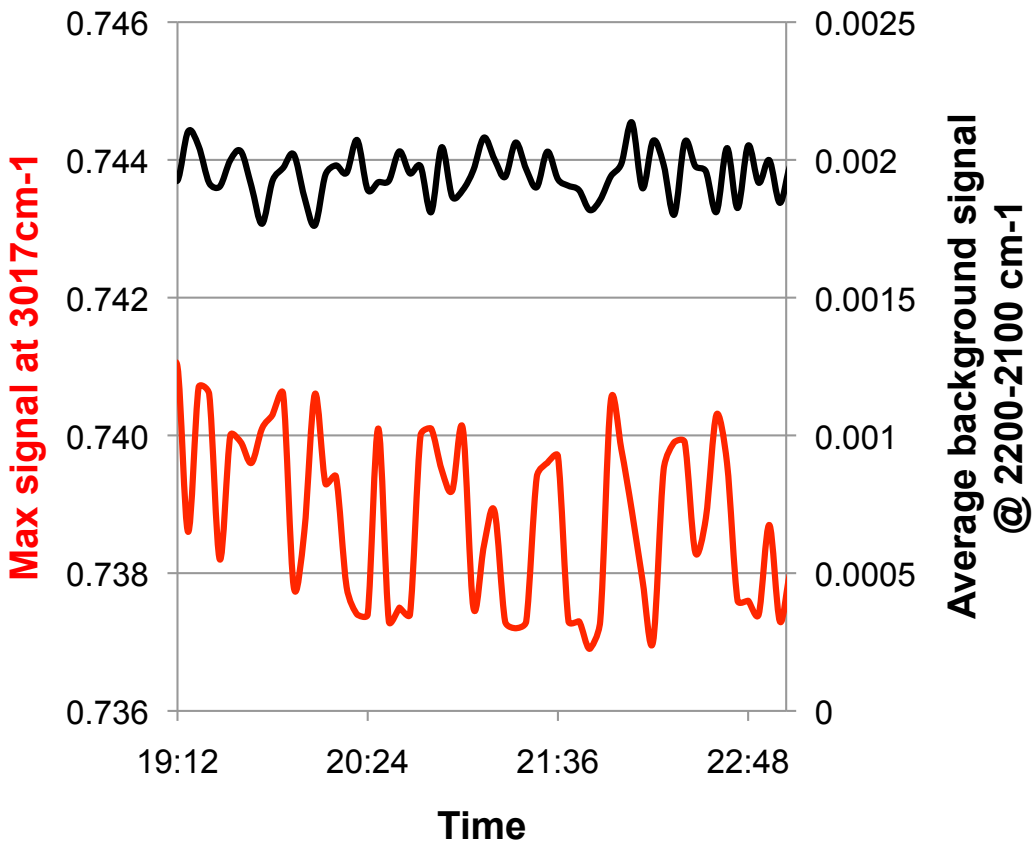
SNR: 2728

Detection limit: 0.4 ppm with 60 s measurement time

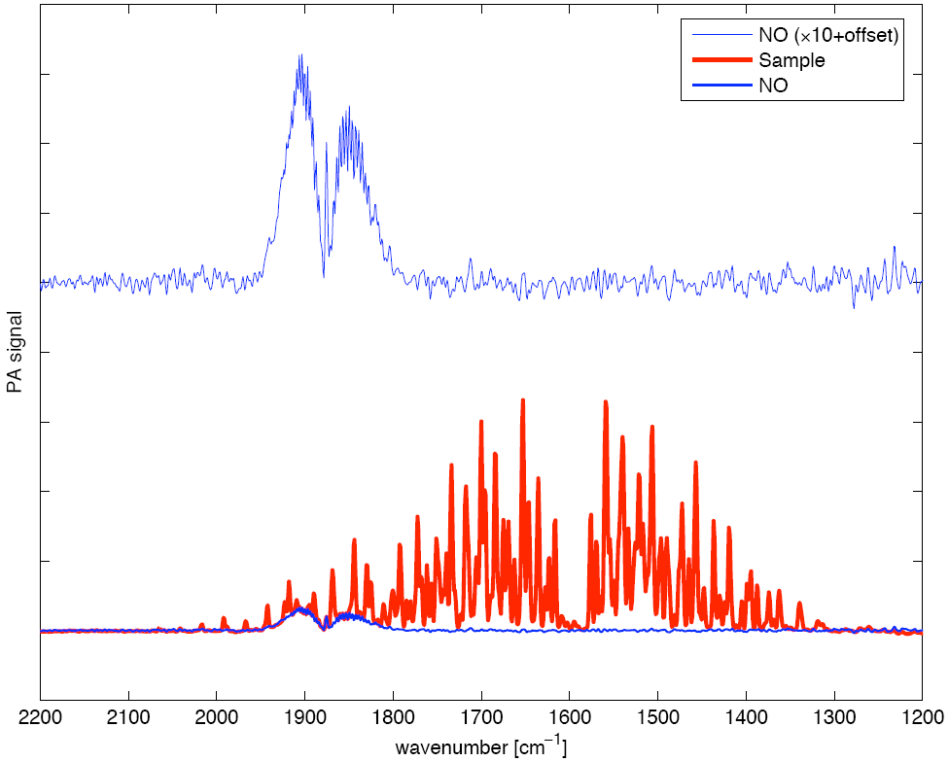


Repeatability

- Measurement with 1000ppm of CH4
- Measurement time over 3 hours
- Repeatability <0.5% (peak to peak measured from signal@3017cm-1)
- Background repeatability <0.05% of the signal
- Fluctuation of the instrument IR source power are also included in the measurement results
- Measurement time: 1 min



Water subtraction with PA101

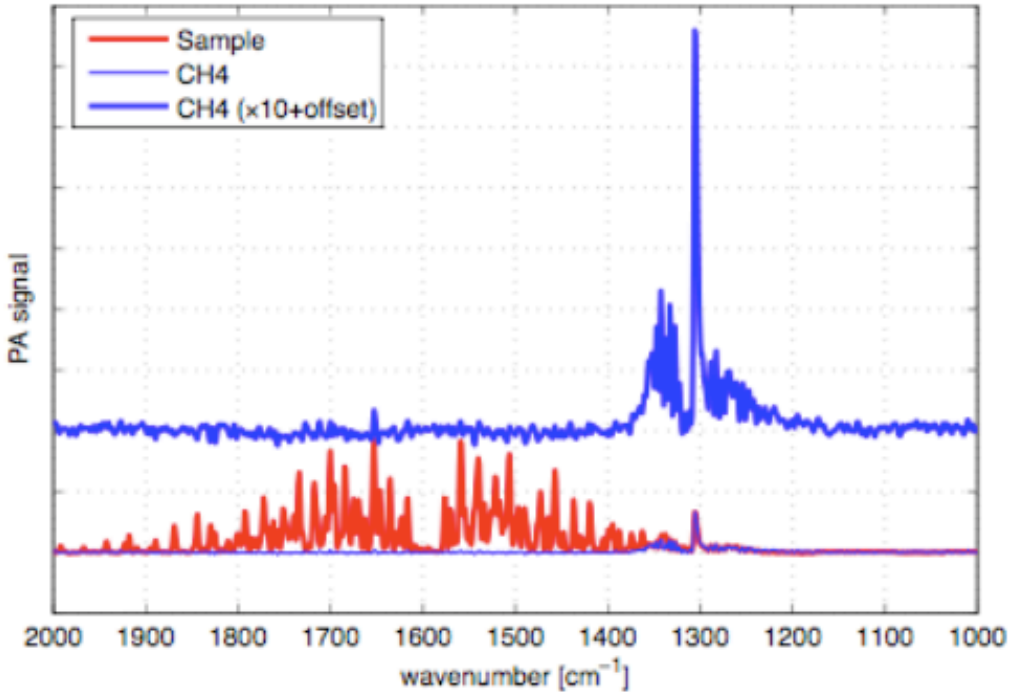


- Short optical path length gives linear response on a wide dynamic range.
- Linear response allows linear spectral mathematics, e.g. subtraction of two spectra.

- Bruker Tensor 27 + PA101 accessory
- 90 ppm NO sample with high concentration of residual water
- Water spectrum for subtraction was measured from ambient air

Wet methane - 100 ppm

- Bruker Tensor 27 + PA101 accessory
- 100 ppm CH4 sample with high concentration of residual water
- Water spectrum for subtraction was measured from a sample created with a gas generator



Low volume

- The low total volume of system gives high sensitivity when only small amount of gas is available.
- The gas exchanger allows the recirculation of this gas which enables e.g. monitoring of system which emits gas with low concentration.
- E.g. if the sample emits N units of gas molecules and it is connected to system of 1 L the concentration is N/1 L. When connected to PA101 with volume of 30 ml and with e.g. 70 ml external volume, the glass and tubes, the concentration is 10 N/ 1 L – **10 times higher sensitivity!**

Applications

- Low sample volume applications:
  - Headspace analysis
  - Analysis of synthesis processes
  - Analysis of decomposition processes
  - Outgassing of materials
- Wet gases
- Measurements requiring wide dynamic range