PICARRO

Providing Solutions to the World's Most Challenging Environmental Questions

May 2023

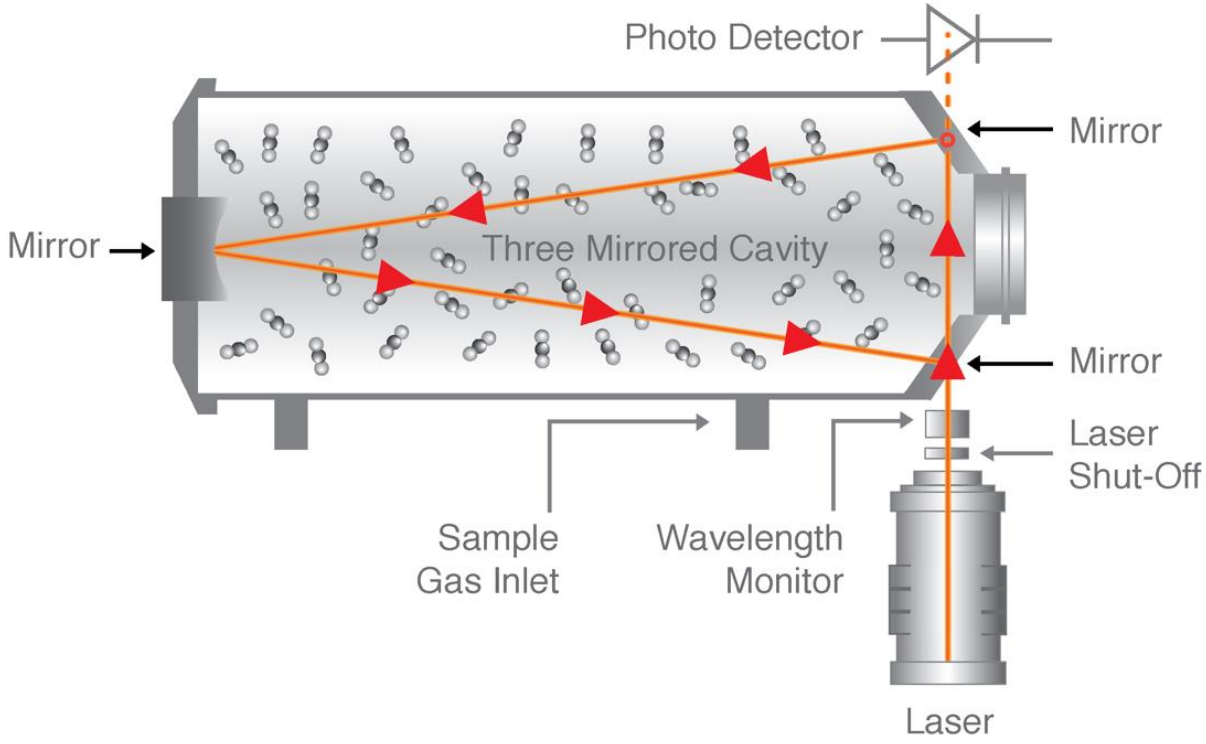
WHO
ARE WE?

- **Leading provider of solutions** to measure greenhouse gas concentrations, trace gases and stable isotopes across **many scientific applications**, along with the **energy and utilities** markets.
- Over 45 patents owned by Picarro or exclusively licensed from Stanford University
- ISO 9001:2015 Certified Corporate Headquarters, including R & D, Engineering and Manufacturing/Operations in Santa Clara, California
- 300+ employees
- Thousands of Picarro instruments in 95 countries world-wide

CERTIFIED ISO 9001:2015 COMPANY

Cavity ring-down Spectroscopy (CRDS)

Time, Not Absorbance

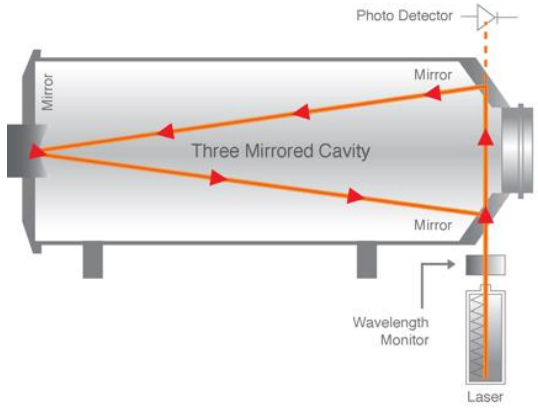


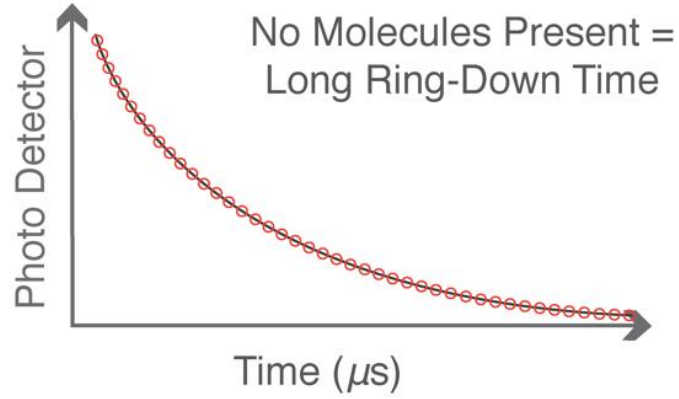
- CRDS utilizes the unique infrared absorption spectrum of gas-phase molecules to quantify the concentration of (and sometimes isotopes of) H_2O, CO_2, CH_4, N_2O, CH_2O, NH_3, etc.
- Measure decay rate, rather than absolute absorbance
- Small 3-mirrored cavity ~ 35 cc
- Long effective path-length (up to 20 km)
- Time-based measurement
- Laser is switched on and off, and scanned across wavelengths

Increasing Concentrations Faster Ring-Down

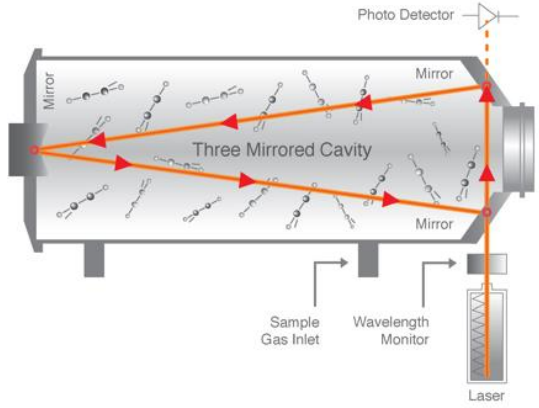
Absorbing species follow Beer-Lambert Law

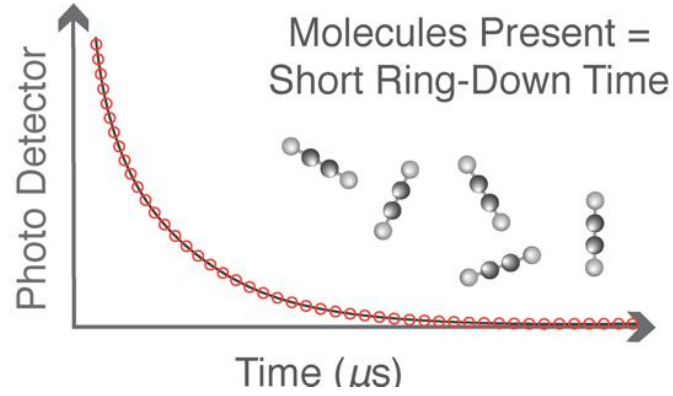
No gas molecules in cavity (or absorbing at measuring frequency)





Gas molecules in cavity (gas absorbing at measuring frequency)



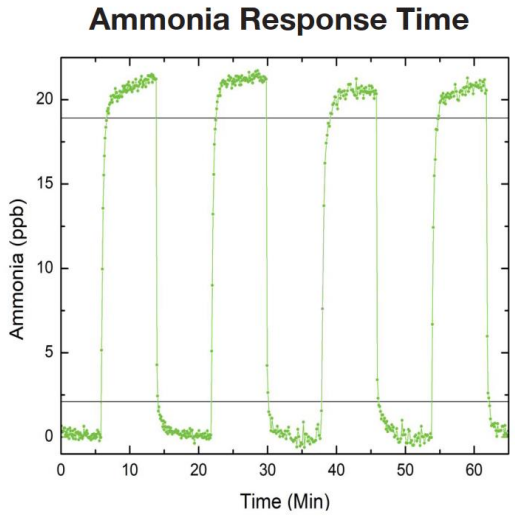


Deployed Across the Globe, in any Situation

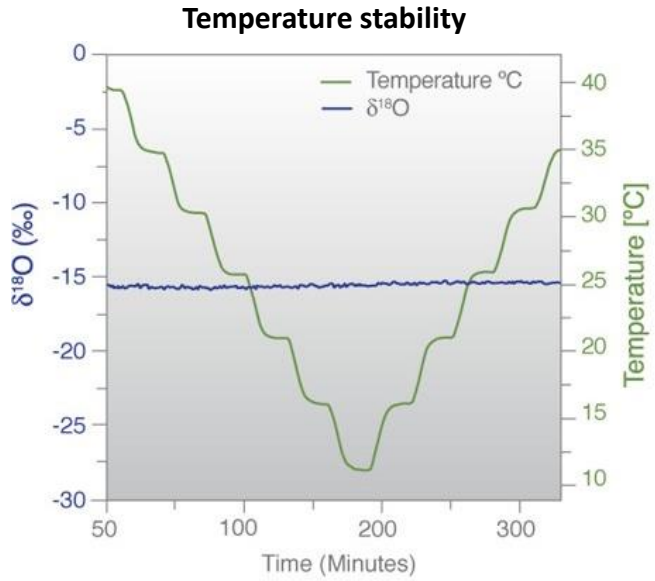
What sets Picarro apart?

- **Speed:** Fast response time
- **Sensitivity:** Extreme precision: ppb or better precision
- **Simplicity:** No need for constant adjustment to atmospheric changes
- **Selectivity:** Interference free: no influence from water or other components
- **Species:** Up to 5 species (water + additional molecules)
- **Stability:** Extremely low drift: stable for months in the field without calibration

  No environmental influences from temperature, pressure or vibrations



Typical response time for a 10-90% and 90-10% 20 ppb ammonia challenge.



Overview Picarro analyzers

GHG analysis

G2301 : CO_2, CH_4, H_2O
G2401 : CO_2, CH_4, CO, H_2O
G2401-m: CO_2, CH_4, CO, H_2O (flight)
G5310 : N_2O, CO
G2508 : N_2O, CO_2, CH_4, (NH_3), H_2O
G2509 : N_2O, CO_2, CH_4, NH_3, H_2O

Suitable for concentration analysis in the atmosphere. Analyzers are optimized for atmospheric concentrations.

Trace gas analyses

SI2103: NH_3, Ammonia
PI2114: H_2O_2, Hydrogen Peroxide
G2307 : H_2CO, Formaldehyde
SI2205: HF, Hydrogen Fluoride
SI2108: HCl, Hydrogen Chloride
SI2104: H_2S, Hydrogen sulfide
G2910/G2920: C_2H_4O, Ethylene Oxide

Suitable for trace gas detection with a specified lower detection limit, for industrial and atmospheric use.

Isotopic analyzers

G2131-i : $\delta^{13}C$ of CO_2
G2201-i : $\delta^{13}C$ of CO_2 & CH_4
G2210-i : $\delta^{13}C$ of CH_4 & C_2H_6

L2130-i : $\delta^{18}O$ & δD of H_2O
L2140-i : $\delta^{18}O$, $\delta^{17}O$, δD &^{17}O-excess

Suitable for field-based monitoring and laboratory application, can be used with different peripherals.

Picarro's ammonia analyzers

Model	CO_2	CH_4	N_2O	H_2O	NH_3
G2103	(s)			(s)	X
G2508	X	X	X*	X	(s)
NEW G2509	X	X	X*	X	X

X: primary measurement
s: secondary measurement
*: additional corrections for NH_3>2ppm

The Picarro G2509 analyzer

G2509

5 species:

- CO_2 (ppb precision)
- CH_4 (ppt precision)
- N_2O (ppb precision)
- NH_3 (ppt precision)
- H_2O

- **Livestock farming, manure processing, and fertilizer studies**
- **Improved NH_3 performance:**
  - Response time
    - Coating for sampling handling parts
    - Increased flow rate (ca. 1.3L/min instead of 240mL/min)
  - Accurate ammonia measurements up to 50 ppm
- **Extended CH_4 range (up to 800ppm)**
- **Surrogate gas validation**
- Proven as ‘customized G2508’ since 2018

Interview with Anders Feilberg

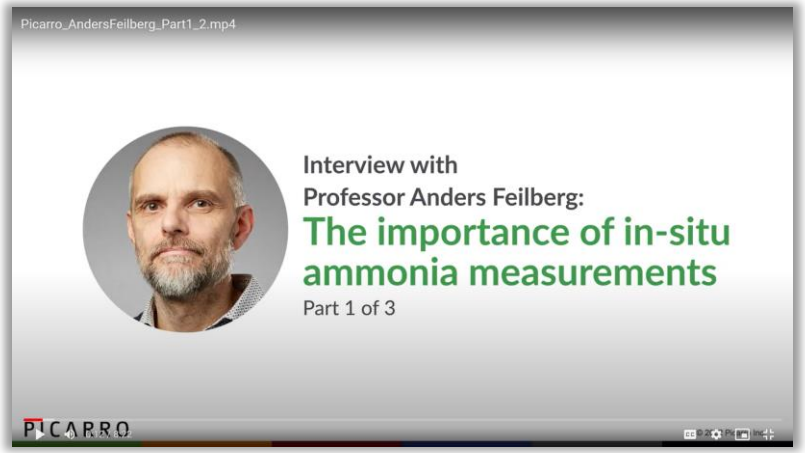
About Anders Feilberg

- Associate Professor at Aarhus University, Denmark
- Key opinion leader for livestock measurements
- Experience with Picarro: Working with Picarro analyzers since 2015

Key statements

- Negligible interference in barn environments (Kamp *et al.*, 2019)
- High sensitivity for ammonia measurements in the field
- Comparable ammonia sensitivity of G2103 and G2509

Full interview can be found on G2509 product page:
https://www.picarro.com/products/g2509_gas_concentration_analyzer



Picarro G2201-*i* CH_4 and CO_2 isotope analyzers

The following measurements are available (also in one unique field deployable analyzer):

- Measure $\delta^{13}C$ in CO_2 <0.1 ‰ precision (5 min average)
- Measure $\delta^{13}C$ in CH_4 <0.8 ‰ precision (5 min average)
- Simultaneously measure CO_2 and CH_4 concentration

Excellent precision at a fraction of IRMS operating cost – less calibration, less maintenance, no consumables

Applications: soil chamber studies, enrichment studies, discrete gas analysis, $\delta^{13}C$ of solids (CM-CRDS), $\delta^{13}C$ of dissolved gases, $\delta^{13}C$ of DIC etc.

eosAC

APPLICATION NOTE 0019

Measuring Isotopic CO_2 and CH_4 Soil Flux with the Picarro G2201-*i*

Introduction

Stable carbon isotope measurements of CO_2 and CH_4 are frequently used to understand the sources and mechanisms contributing to soil gas flux. For example, isotopes of CO_2 can be used to determine the relative contributions of root and microbial CO_2 production to total soil CO_2 flux. Alternatively, in systems where photosynthetic pathways have transitioned from C3 to C4 or vice versa (**Figure 1a**) isotopes can be used to determine relative contributions of carbon from each pathway to total soil respiration. Similarly, methane stable isotopes are used to differentiate biological versus geological sources of soil gas flux (**Figure 1b**) and can also be used to examine the mechanisms of methane production and oxidation. This application note outlines the configuration and use of the Picarro G2201-*i* dual carbon (CO_2 & CH_4) isotope analyzer to differentiate between C3 and C4 respiration sources at a transitional agricultural experiment in southern Sweden.

System Setup
Follow Eosense application note **AN0003** for quick setup of your Picarro G2201-*i* with the eosMX multiplexer and eosAC automated soil flux chambers.

Sample Handling

The Picarro G2201-*i* with A0702 recirculating pump has a nominal flow rate of 25 sccm and is optimized to provide recirculation-based measurements. Due to the low flow rate users must consider the total transit time and mixing time required for chamber measurements. Below in Table 1 the estimated minimum times required by tubing length to deliver the sample to the analyzer are shown.

Tubing Length	Volume	Transit Time
10 m	79 cm^3	3 min
20 m	158 cm^3	6 min
30 m	238 cm^3	9 min

Table 1. Nominal transit times for gas to the G2201-i analyzer assuming tubing with a 3.175 mm (⅛") internal diameter and the Picarro A0702 recirculating pump.

Because the required minimum transit times are quite long, users may wish to implement a secondary pump to speed up the sampling process. Eosense recommends a pump with nominal flow rates of less than 1 SLPM (1000 sccm) that is designed for recirculation applications. **Figure 2** demonstrates the configuration of the secondary pump in the system.

Figure 2. Example diagram of a sub-loop system using an secondary pump to speed up the flow from the eosMX to the G2201-i analyzer. Total system flow rate is the sum of the Picarro pump flow and secondary pump flow.

Figure 1. (a) eosAC chambers coupled to a Picarro G2201-i at the Ultuna site in Uppsala, Sweden (Photo: Muhammad Shahbaz, SLU) (b) Measurements of stable C isotopes near the Daisy Geyser at Yellowstone National Park (Photo: Moyo Ajayi, Vanderbilt University)

eosense.com

https://www.picarro.com/support/library/documents/eosense_application_note_0019_application_note

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THANK YOU!