UC RIVERSIDE | College of Engineering – Center for Environmental Research and Technology

2023 OSAR CONFERENCE

Moving towards Onboard Sensing, Analysis, and Reporting (OSAR)

March 30 & 31, 2023

# A compact ultra-light laser-based portable emissions measurement system (PEMS) platform for vehicle emissions measurements

**Ritobrata Sur**
**Indrio Technologies Inc.**

INDRIO TECHNOLOGIES

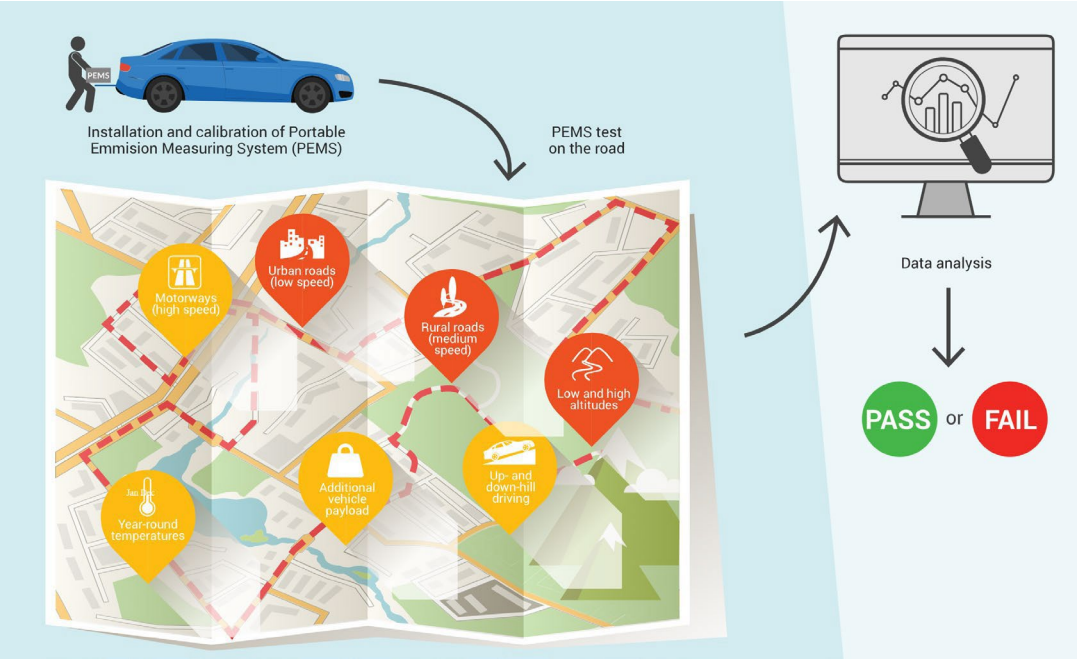
# Outline

- Background
- Problem
- Solutions from Indrio
- Validation data
- Application Examples

# Background

Emissions certification from dynamometer testing paints an incomplete picture

# Portable emissions measurement system (PEMS)




Title 40/Chapter I/Subchapter U/Part 1065/Subpart J

**Real World Emissions Measurements Are Needed**

# Problem with current solutions - Performance

| Parameter | Target PEMS performance (CARB) | Industry best (PEMS) |
|---|---|---|
| $NO_x$ LDL | 0.5 ppm | 1 ppm |
| $NH_3$ LDL | 0.5 ppm | 10 ppm |
| Weight | < 30 lbs | 6 lbs |
| Error | < 10% | Unknown |
| Cross-sensitivity | None | $NH_3$, $H_2O$, Others |
| Time resolution | 0.2 sec | 5 sec |
| Cold Start | Yes | No |

A typical PEMS unit

https://doi.org/10.1016/j.scitotenv.2019.136366

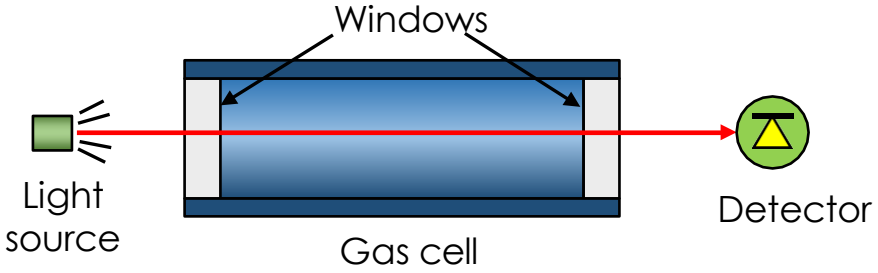
# Problem with current solutions - Portability

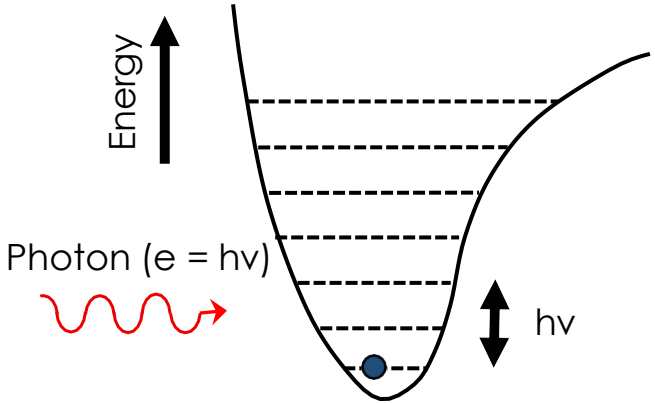
| | |
|---|---|
| Global MRV, AIP<br>MAHA, AVL, Horiba | Undesirable for PEMS |
| Missing, Ideal PEMS | ECM, 3DATX,<br>PhotoVAC |

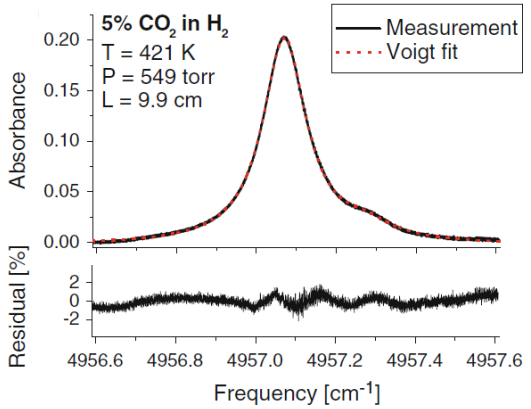
Weight ↑

$NOx/NH_3/N_2O$ detection limit →

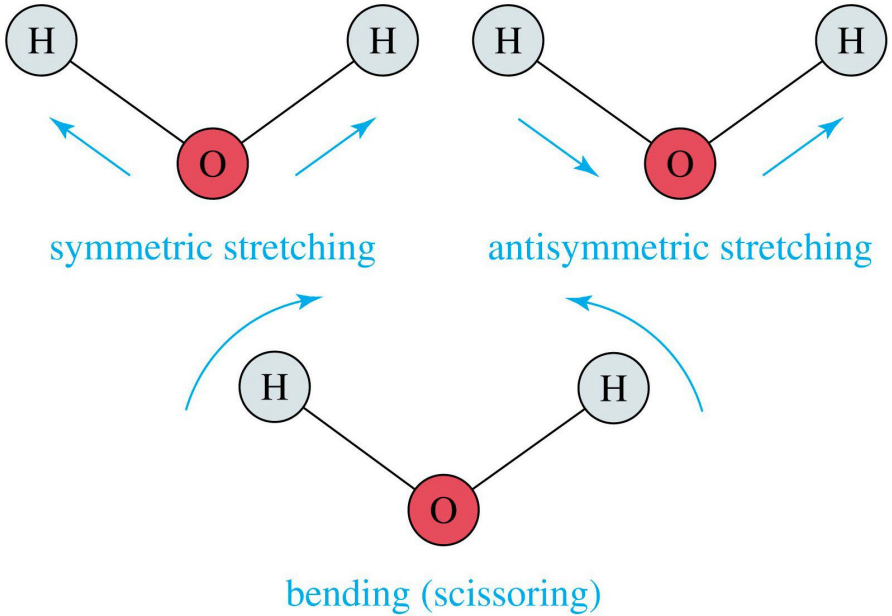
# Laser spectroscopy-based solution from Indrio (Fundamentals)



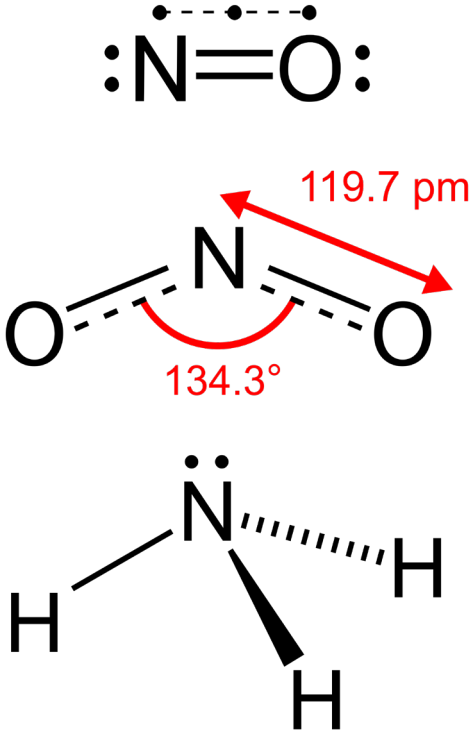



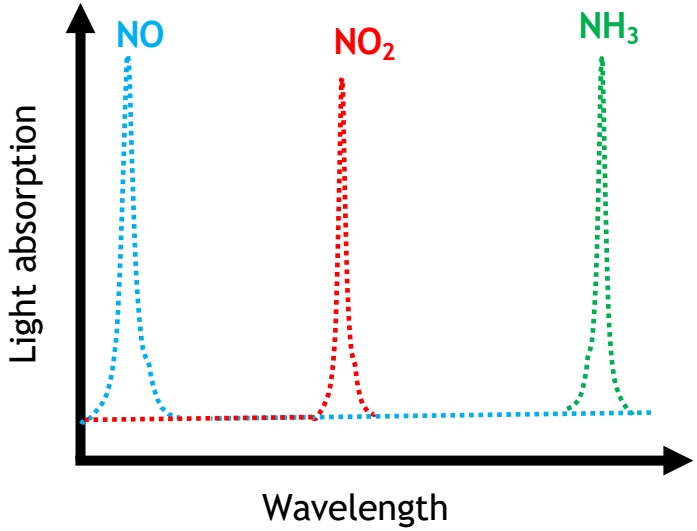



# Specific modes of vibration – molecule-specific



# Specificity



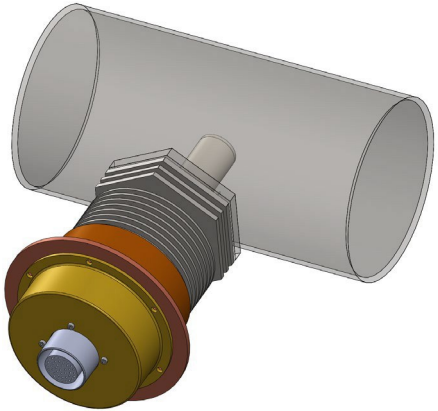



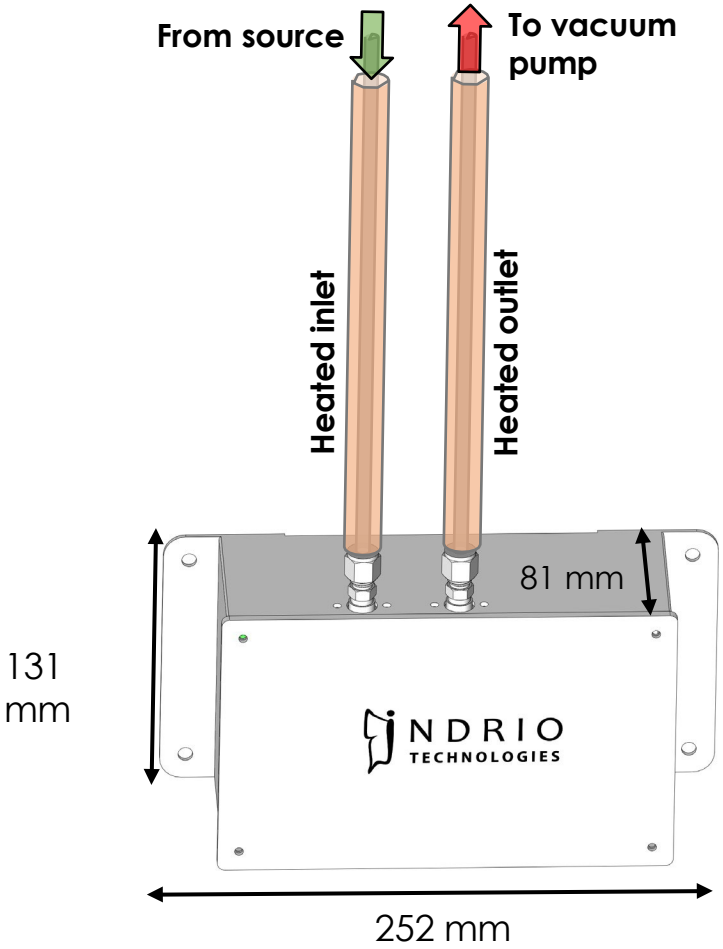

**Unique molecular signature for NO, $NO_2$ and $NH_3$ ➡ No interference!!**

# Indrio sensor types

Sampling-based
(Zephyr)


In-exhaust
(Ignis)





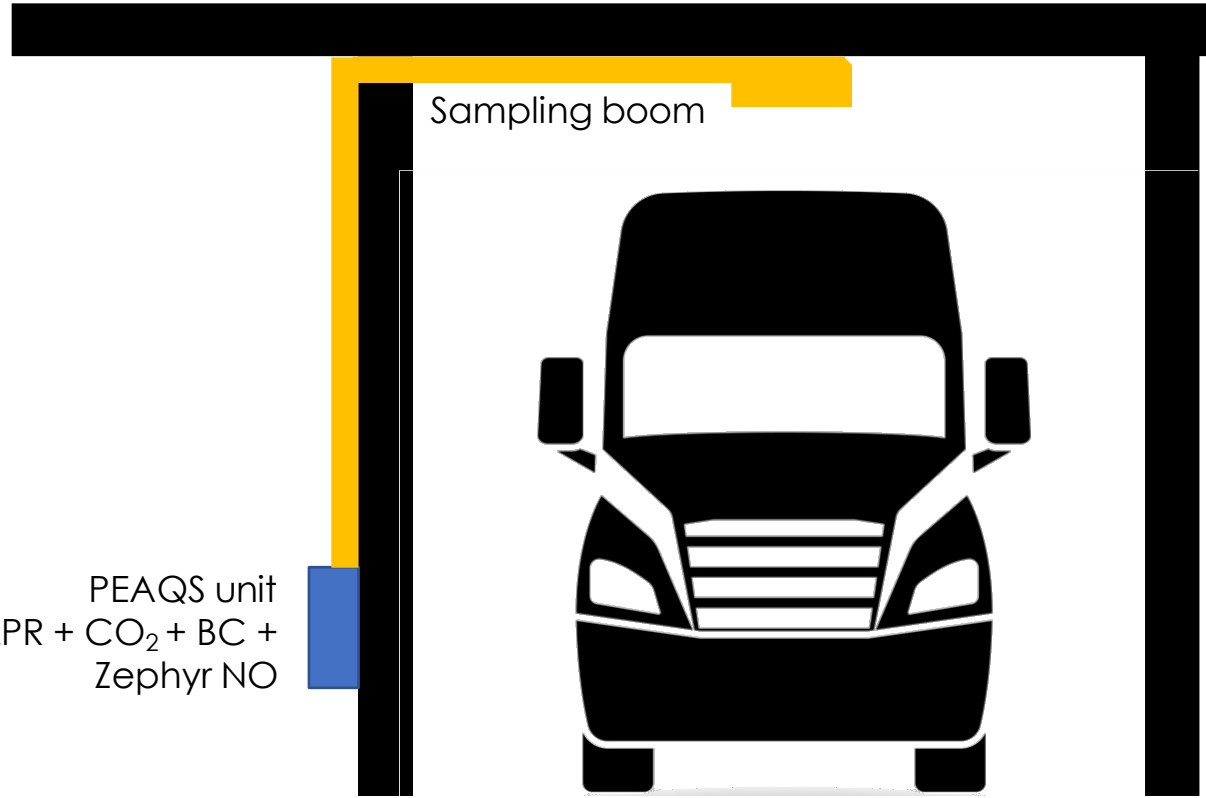

# Zephyr Sensors (Heated & Externally pumped)

Size: 252 mm x 131 mm x 81 mm.

Detection range:
NO: 0.3 ppm - 600 ppm
$NO_2$: 0.2 ppm - 400 ppm
$N_2O$: 0.05 ppm - 100 ppm
$NH_3$: 0.2 ppm - 400 ppm

Weight: 5 lbs

# Zephyr use case: field-deployable stationary unit

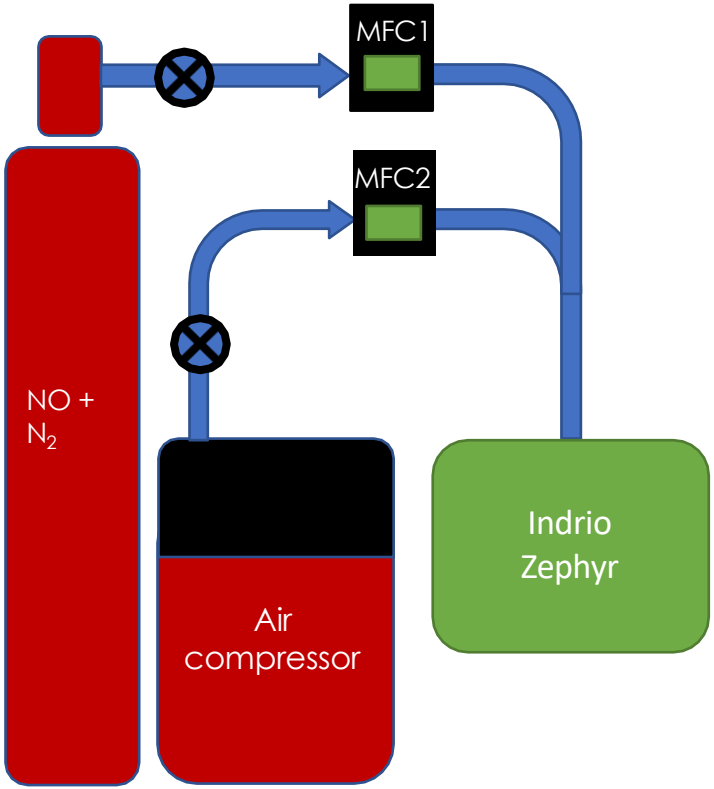


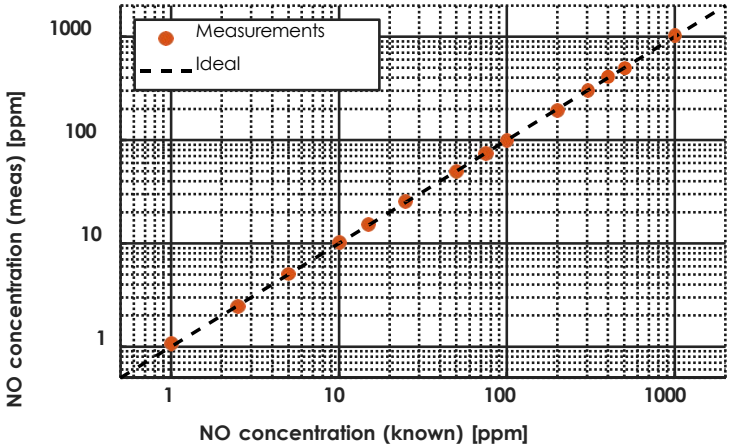


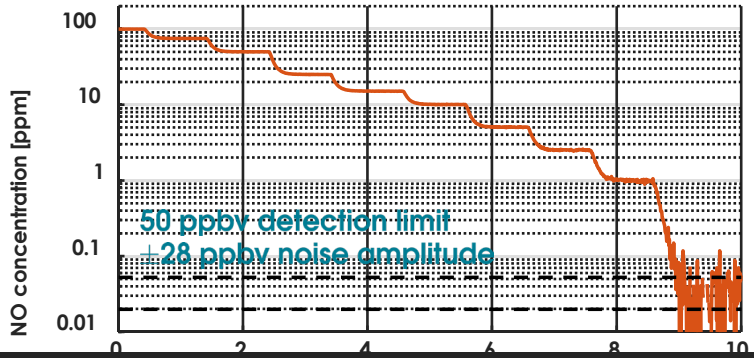
Portable Emission Acquisition System (**PEAQS)**

CALIFORNIA AIR RESOURCES BOARD

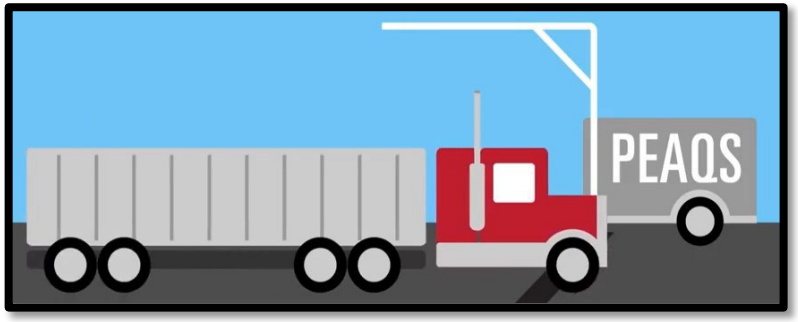
# Lab validation and performance characterization



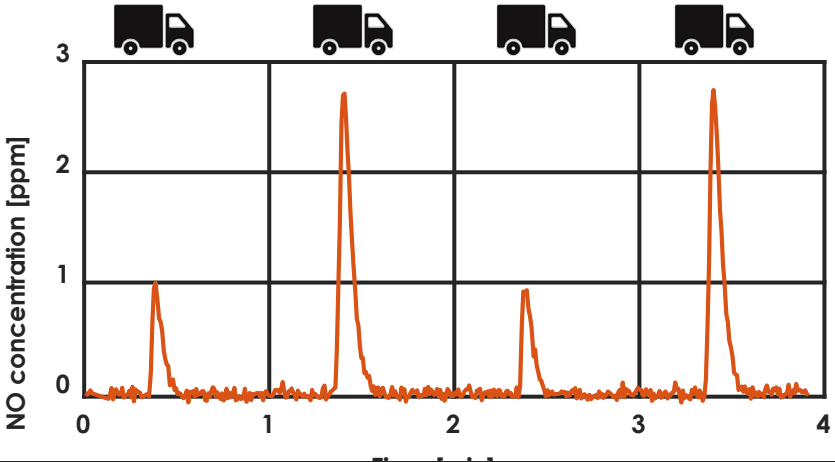



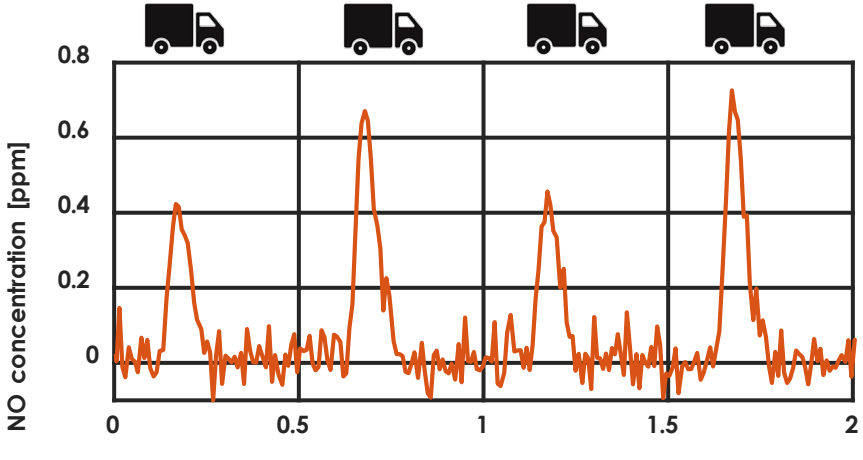
# PEAQS-relevant lab tests




High emitter plume conditions



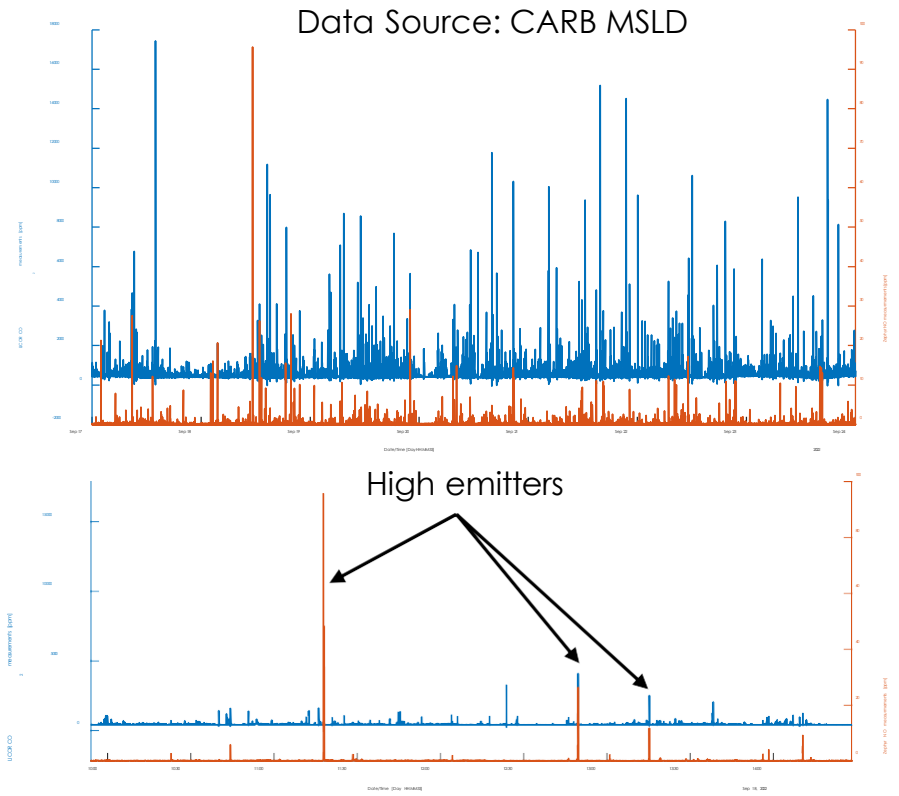

Sub-ppm plume conditions



# PEAQS Deployment Sites

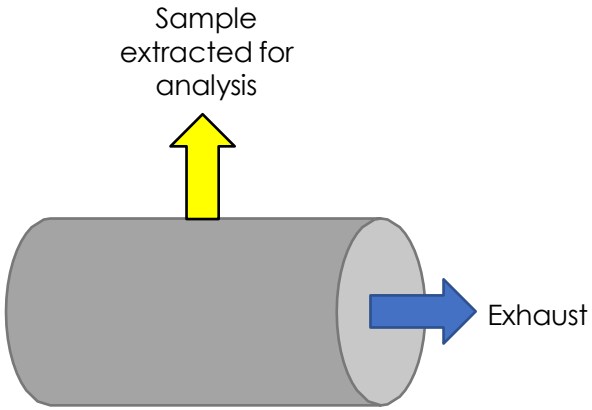




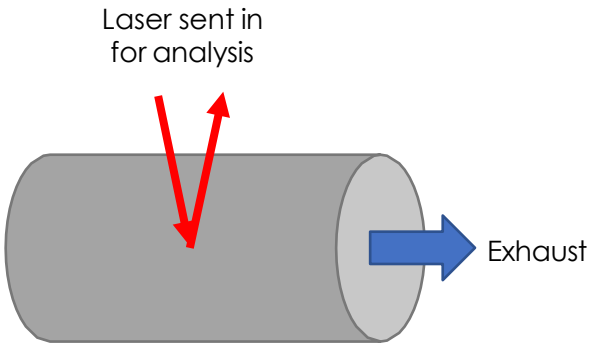


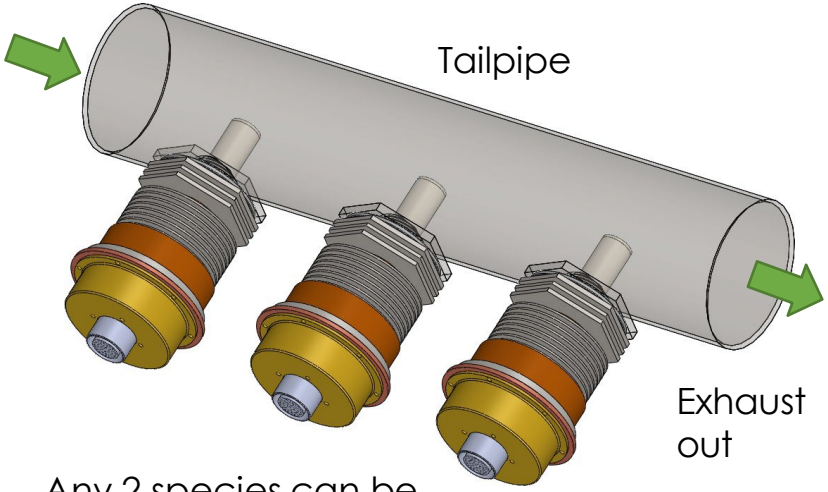
# Core in-exhaust laser sensor concept - Ignis

**Traditional laser-based sensors (PEMS)**




**Ignis sensors from Indrio (PEMS/future OBM)**






Any 2 species can be combined in 1 head

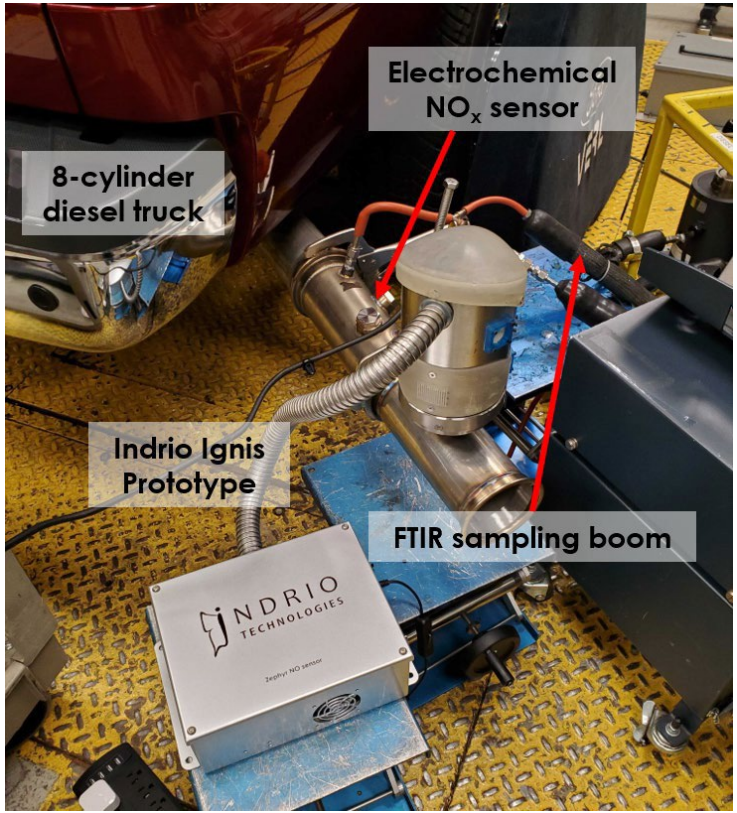
Sensor controller box
2 species per box

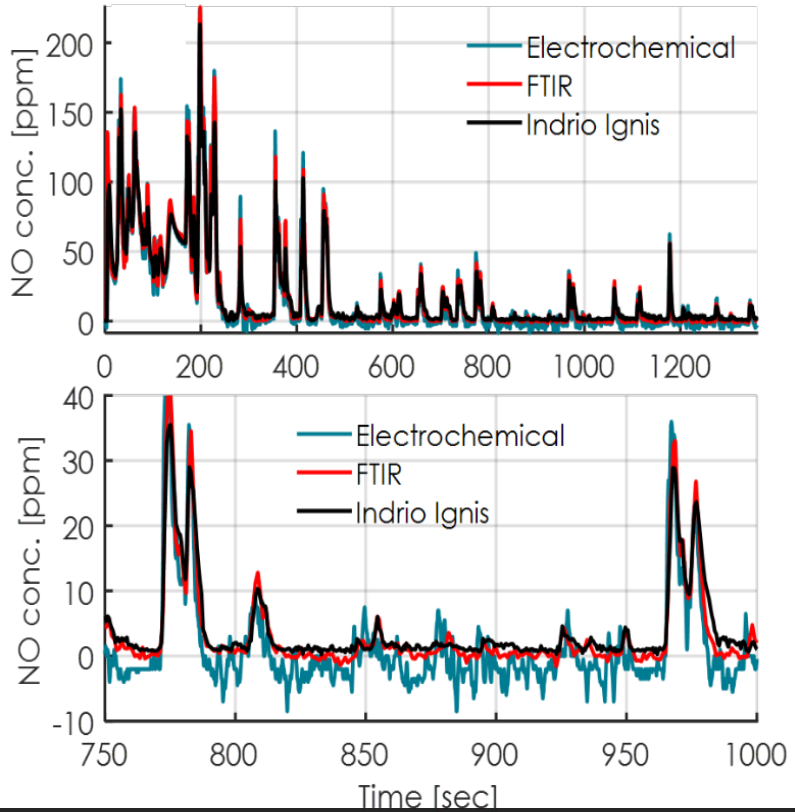

# Ignis (In-situ)

Detection range:
NO: 0.9 ppm - 1800 ppm
$NO_2$: 0.6 ppm - 1200 ppm
$N_2O$: 0.15 ppm - 300 ppm
$NH_3$: 0.6 ppm - 1200 ppm

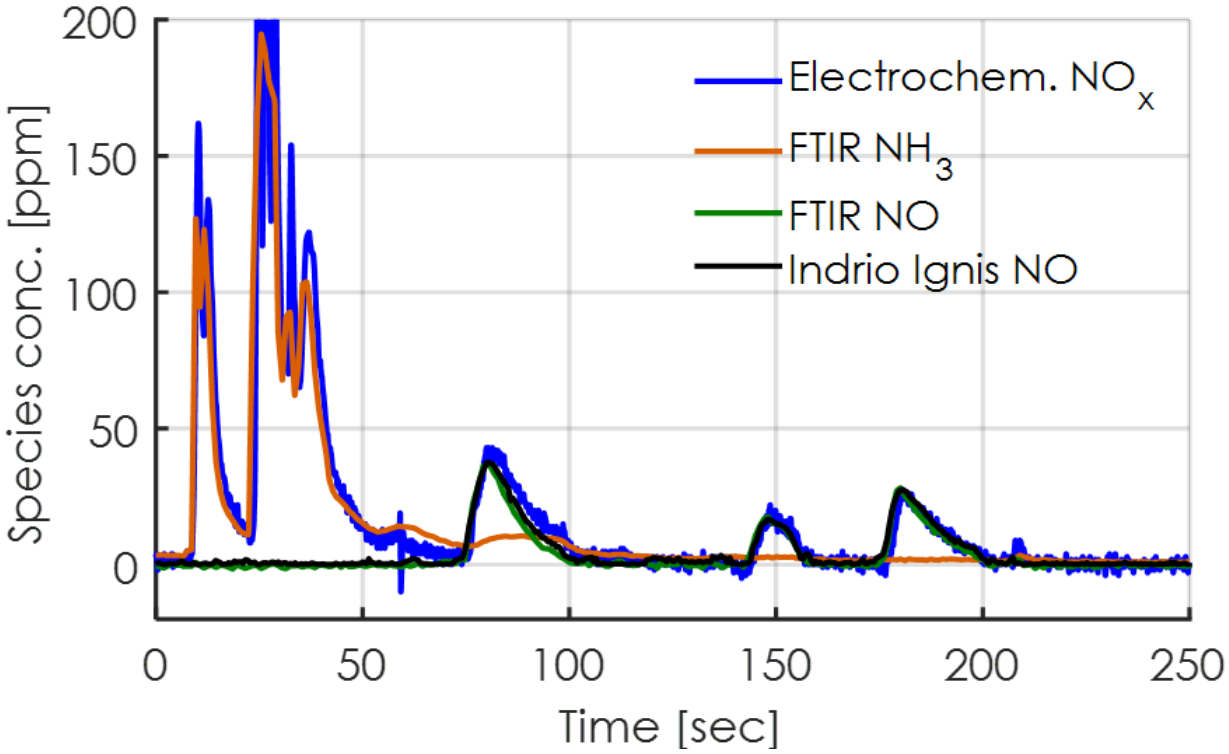
Time Resolution: >5Hz
In-situ probe max temp: 600°C

# Tests at Vehicle Emissions Research Laboratory (Ford)

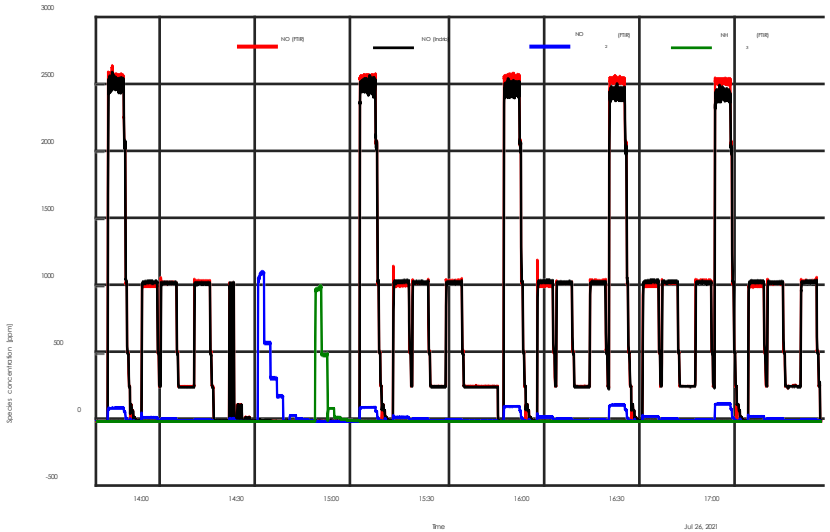


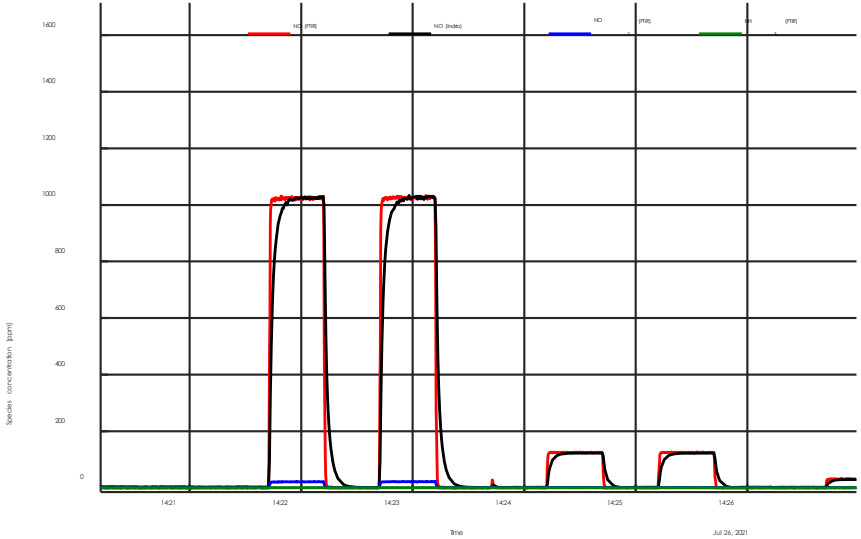



# Zero ammonia interference



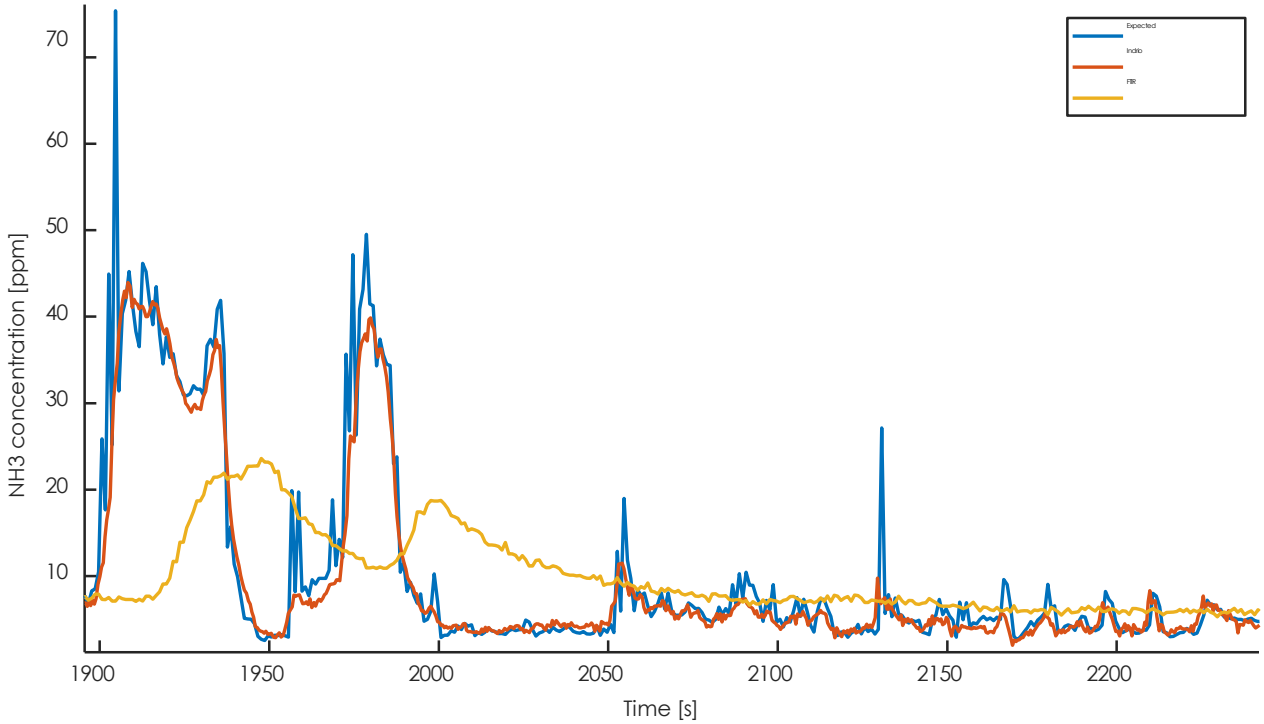
# More Lab test results



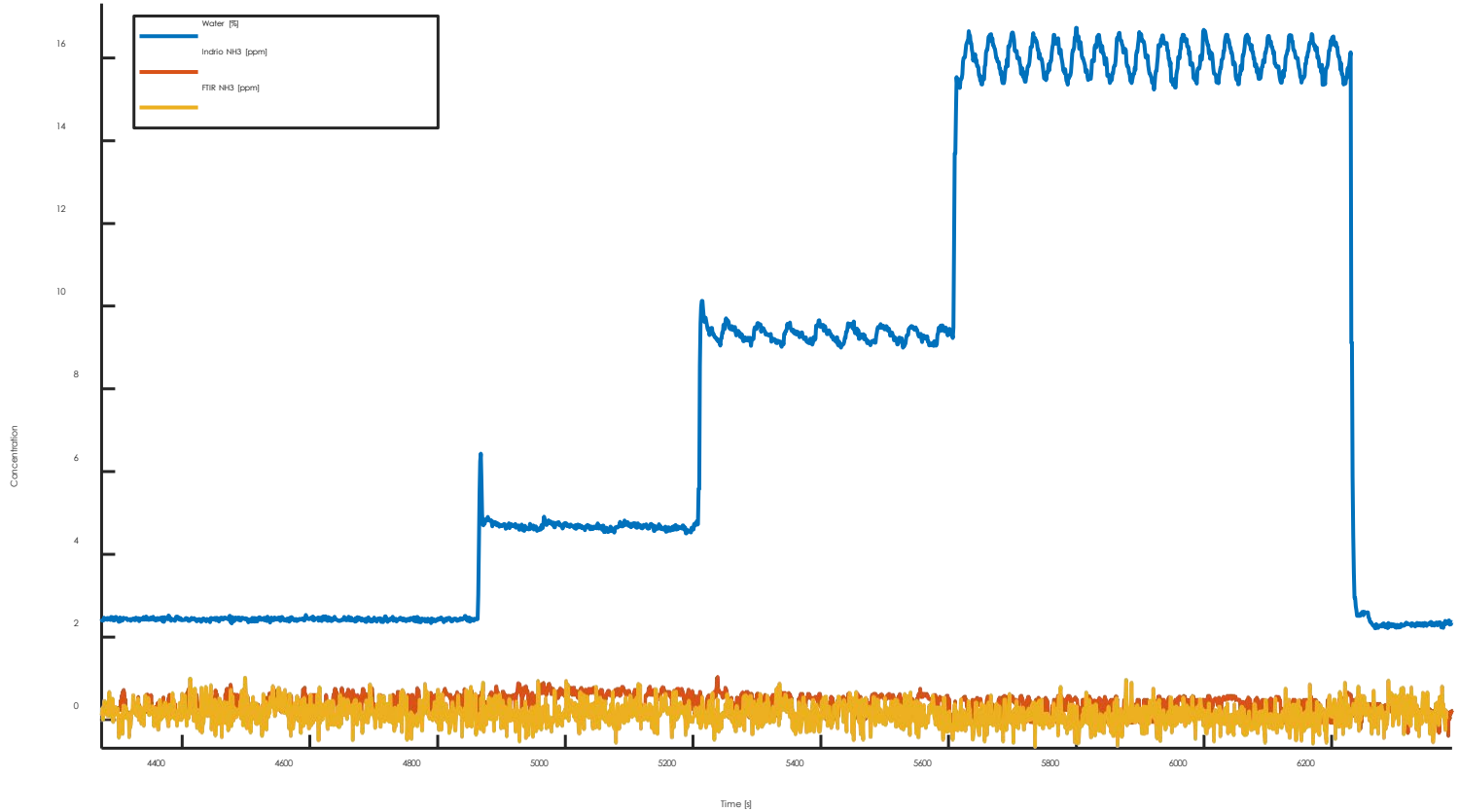

- Results agreed well with lab instrumentation
- 1.5 sec time response (<5 sec required for lab instruments)

# $NH_3$ sensor (SWRI ECTO lab tests, Mar 2022)

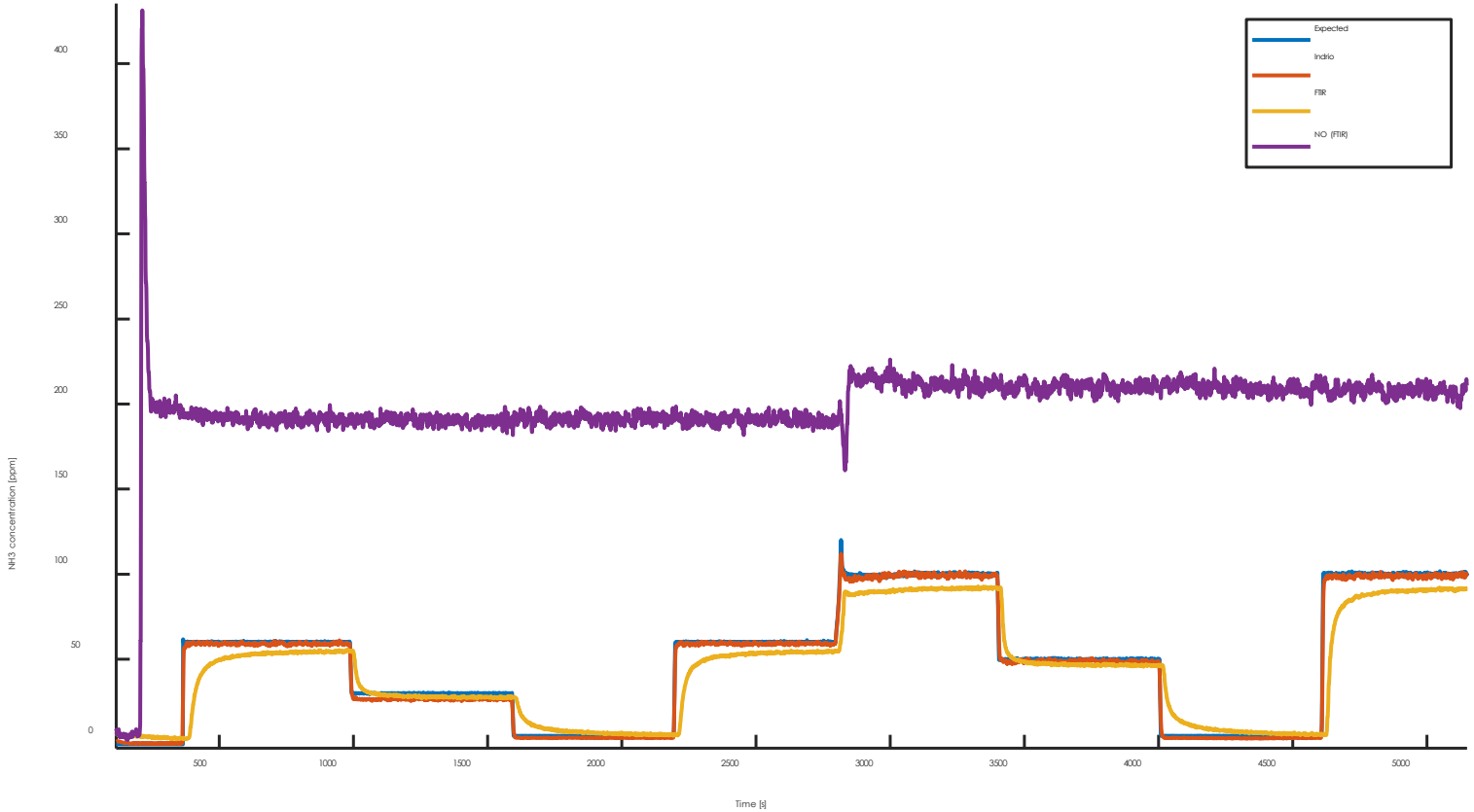



**Indrio's Ignis sensors can track transients significantly better than FTIR**

# Zero water interference



# Zero NOx interference



# Acknowledgements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# Speaker Information

Thank you!

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