

# A COMPACT ULTRA-LIGHT LASER-BASED PORTABLE EMISSIONS MEASUREMENT SYSTEM (PEMS) PLATFORM FOR VEHICLE EMISSIONS MEASUREMENTS

Ritobrata Sur  
Indrio Technologies Inc.

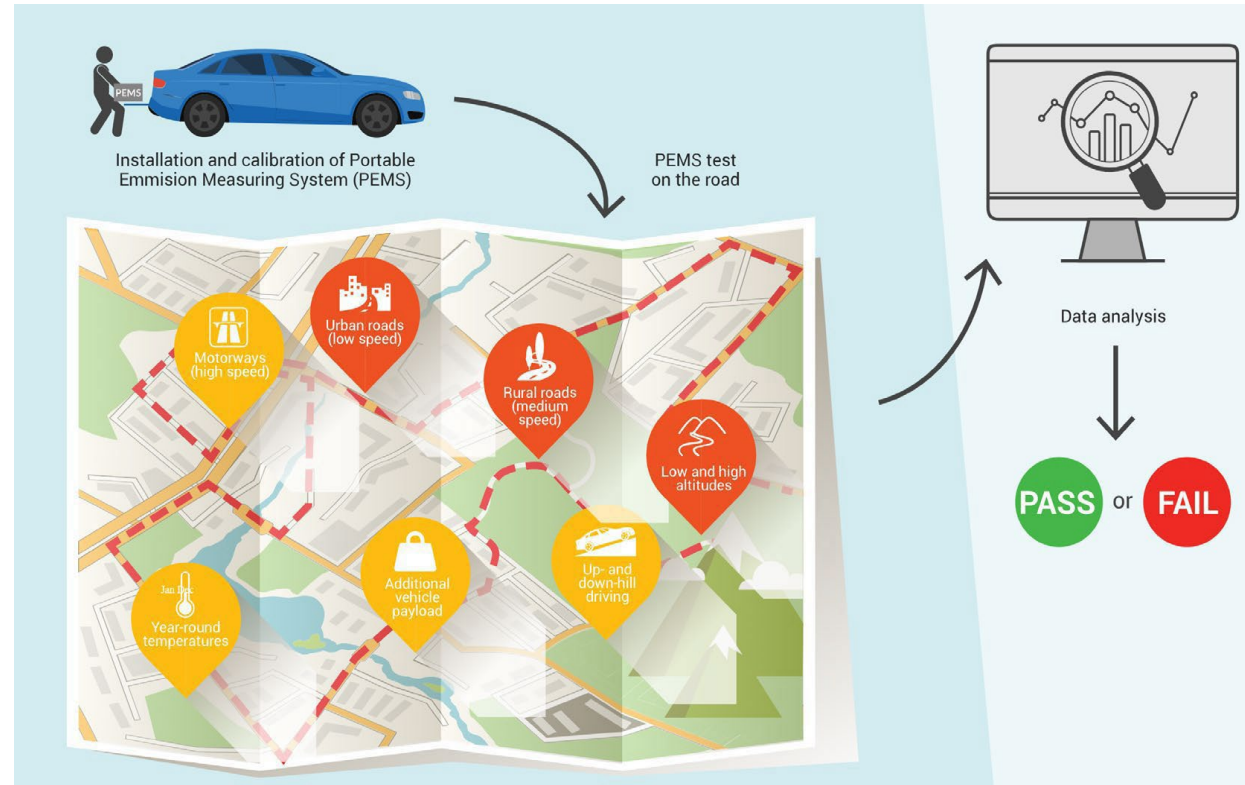


# BACKGROUND



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 (PEMS)
NO <sub>x</sub> LDL	0.5 ppm	1 ppm
NH <sub>3</sub> LDL	0.5 ppm	10 ppm
Weight	< 30 lbs	6 lbs
Error	< 10%	Unknown
Cross-sensitivity	None	NH <sub>3</sub> , H <sub>2</sub> O, 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

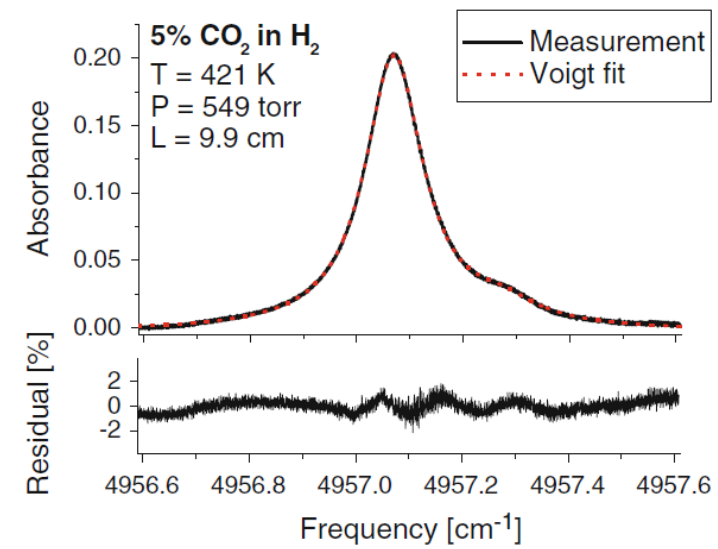
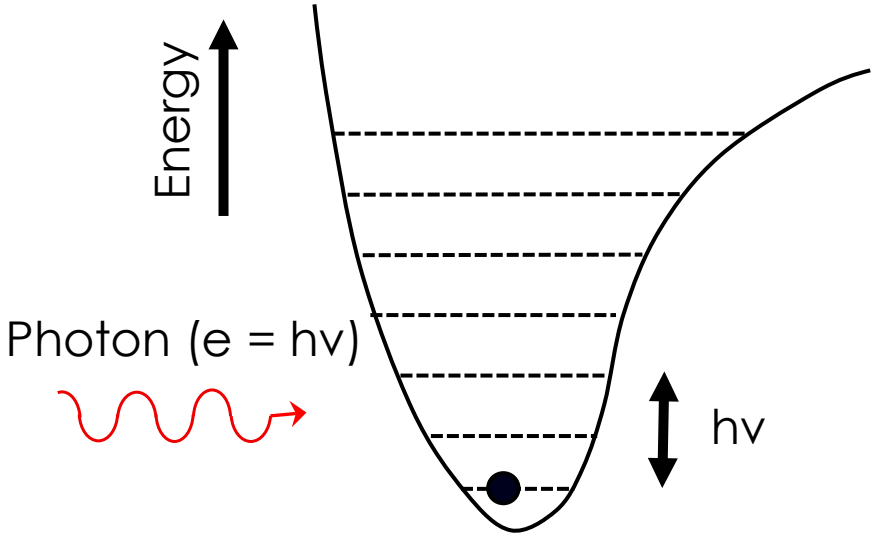
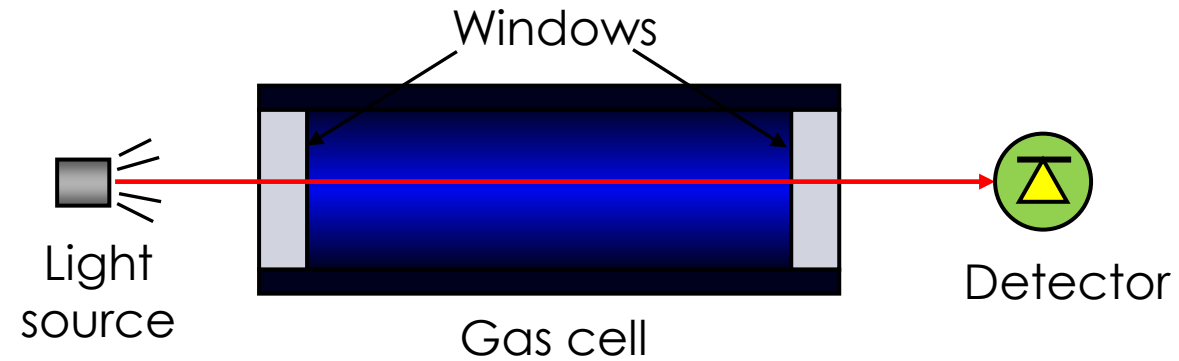
Weight ↑

Global MRV, AIP MAHA, AVL, Horiba	Undesirable for PEMS
Missing, Ideal PEMS	ECM, 3DATX, PhotoVAC

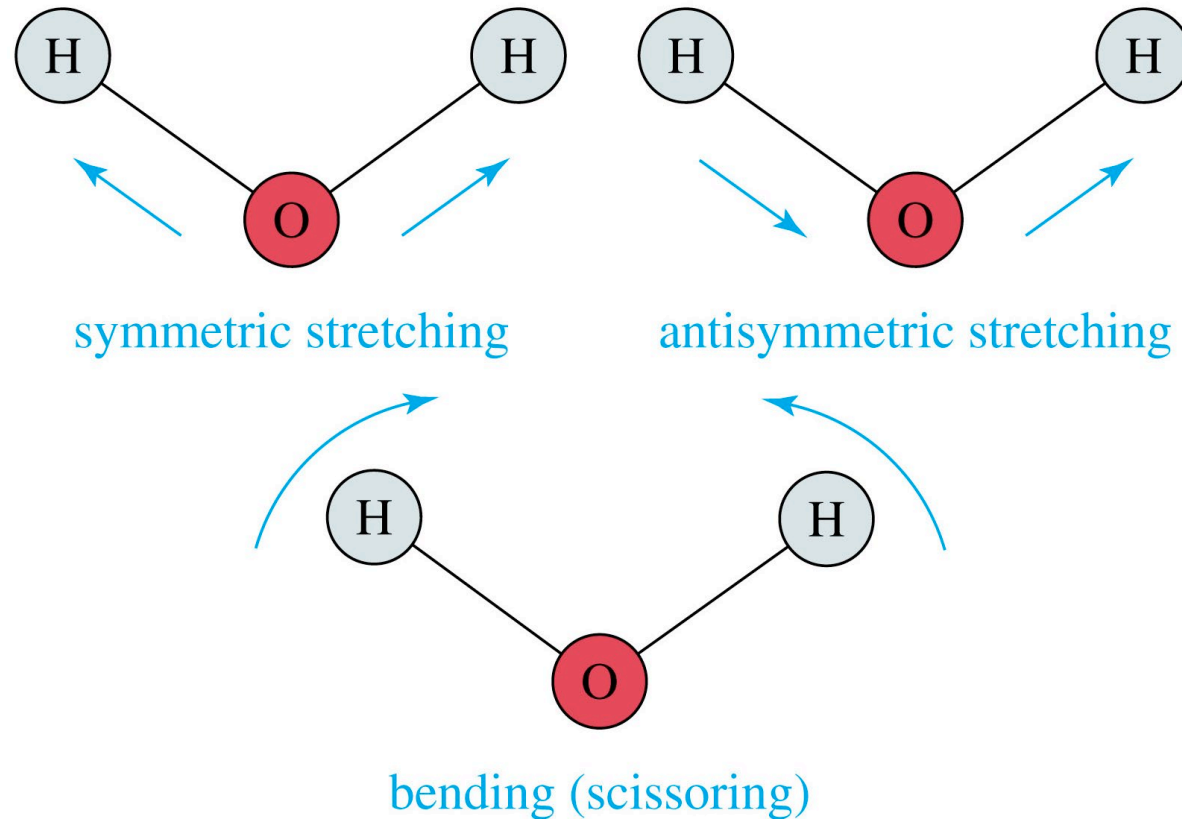
NOx/NH<sub>3</sub>/N<sub>2</sub>O detection limit →



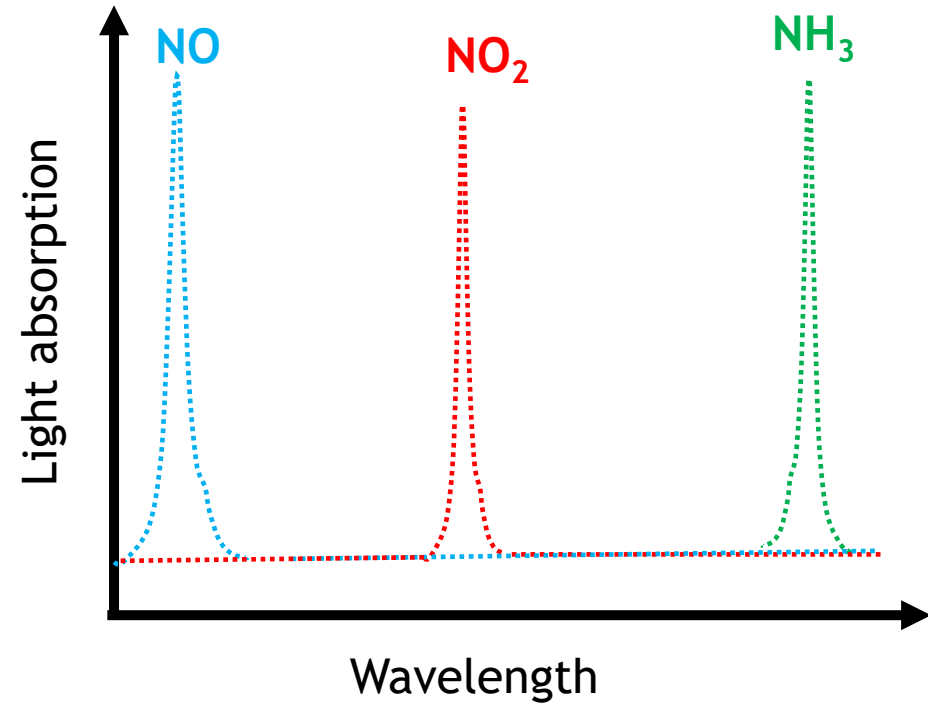
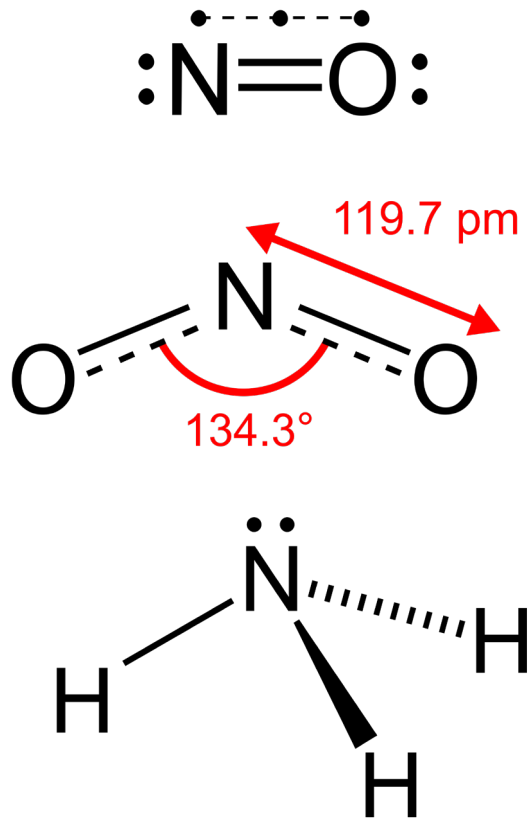
# LASER SPECTROSCOPY-BASED SOLUTION (FUNDAMENTALS)



# SPECIFIC MODES OF VIBRATION – MOLECULE-SPECIFIC



# SPECIFICITY



Unique molecular signature for NO, NO<sub>2</sub> and NH<sub>3</sub> ➔ **No interference!!**

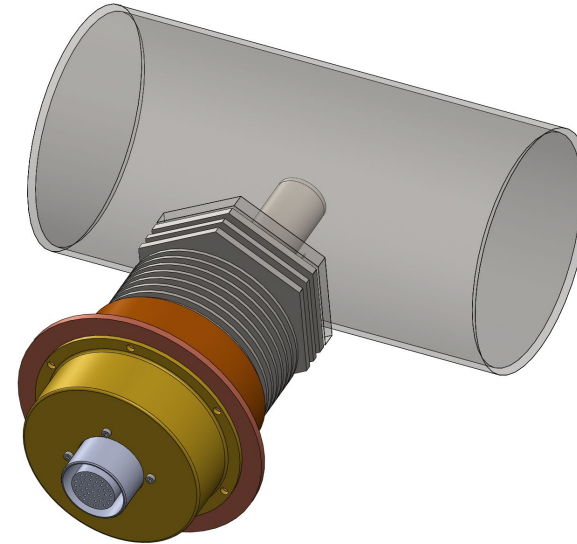


# INDRIO SENSOR TYPES

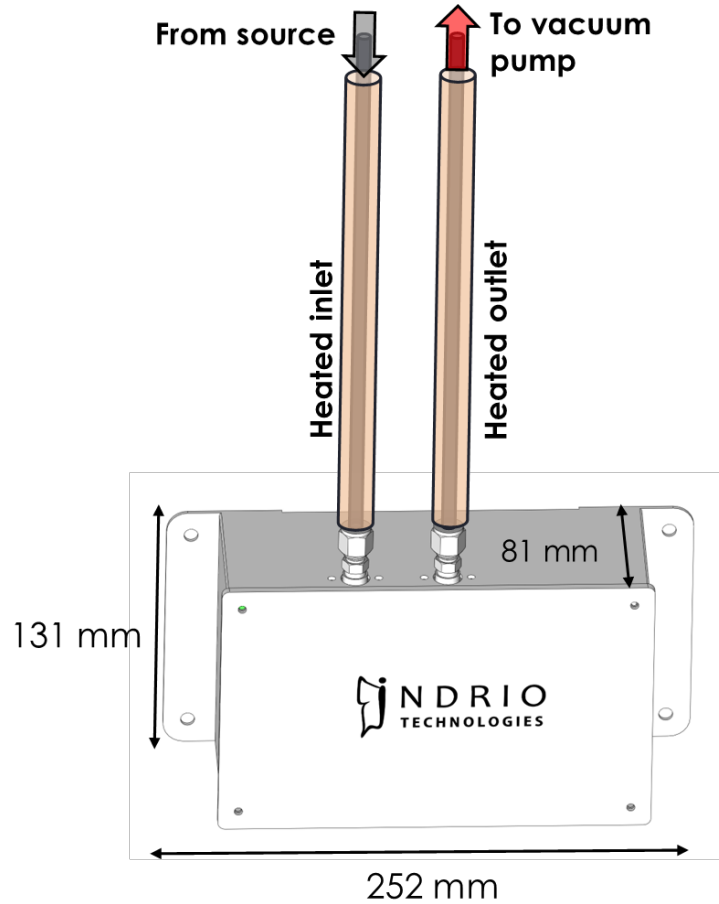
Sampling-based  
(Zephyr)



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<sub>2</sub>: 0.2 ppm - 400 ppm

N<sub>2</sub>O: 0.05 ppm - 100 ppm

NH<sub>3</sub>: 0.2 ppm - 400 ppm

Weight: 5 lbs

# ZEPHYR USE CASE: PORTABLE EMISSIONS MEASUREMENTS

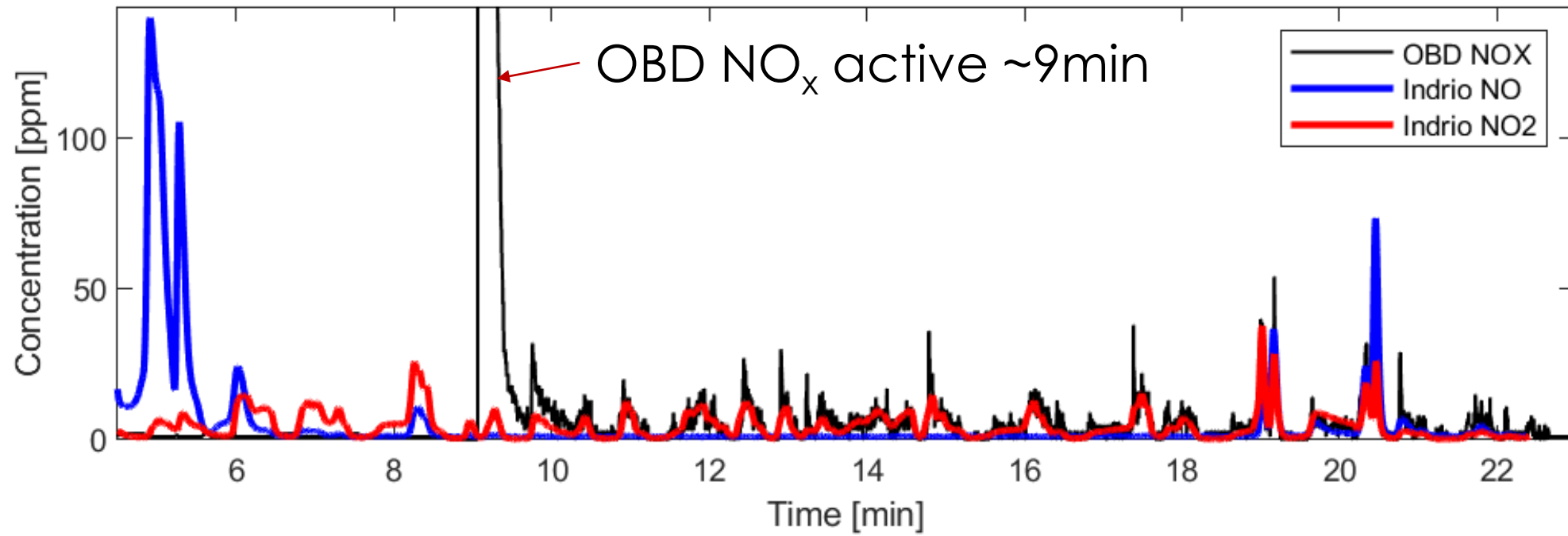
- NOX (NO + NO<sub>2</sub>) PEMS for:
  - Alternative fuels research
  - Fleet analysis of new emissions controls

## Zephyr PEMS Installed on a Mercedes Sprinter Van for Real-World Tests



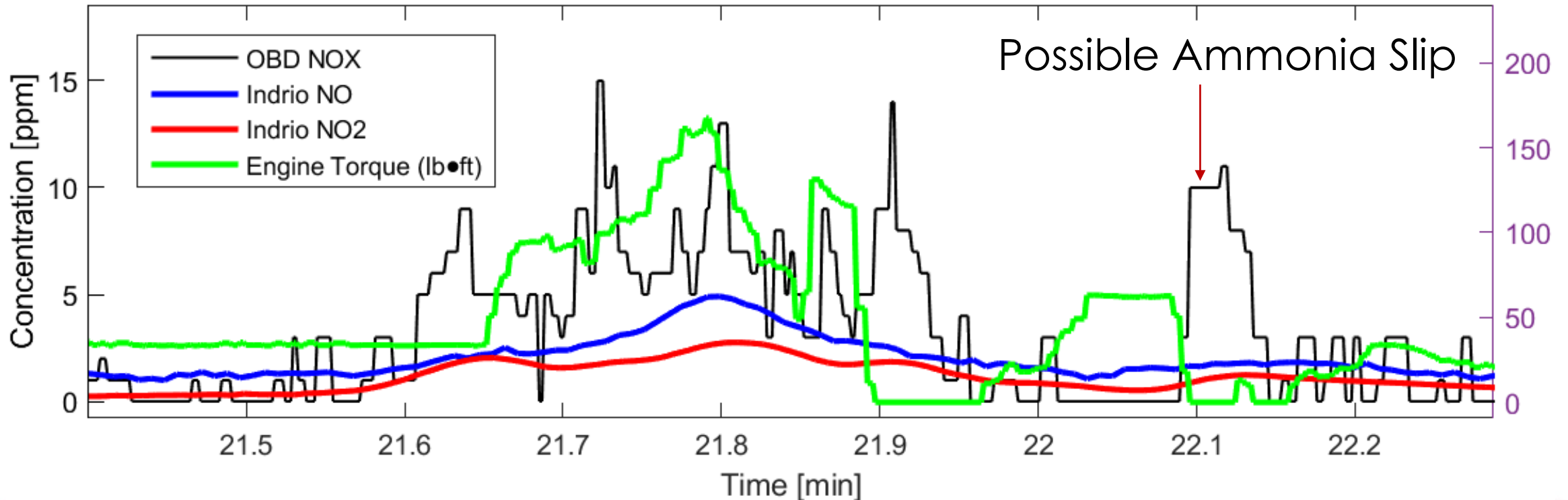
# ZEPHYR NO + NO<sub>2</sub> MEASURED ALONGSIDE OBD NO<sub>x</sub>

- OBD NO<sub>x</sub> takes ~9 min before warmed up and taking data
- Zephyr sees large NO spikes during **cold start**



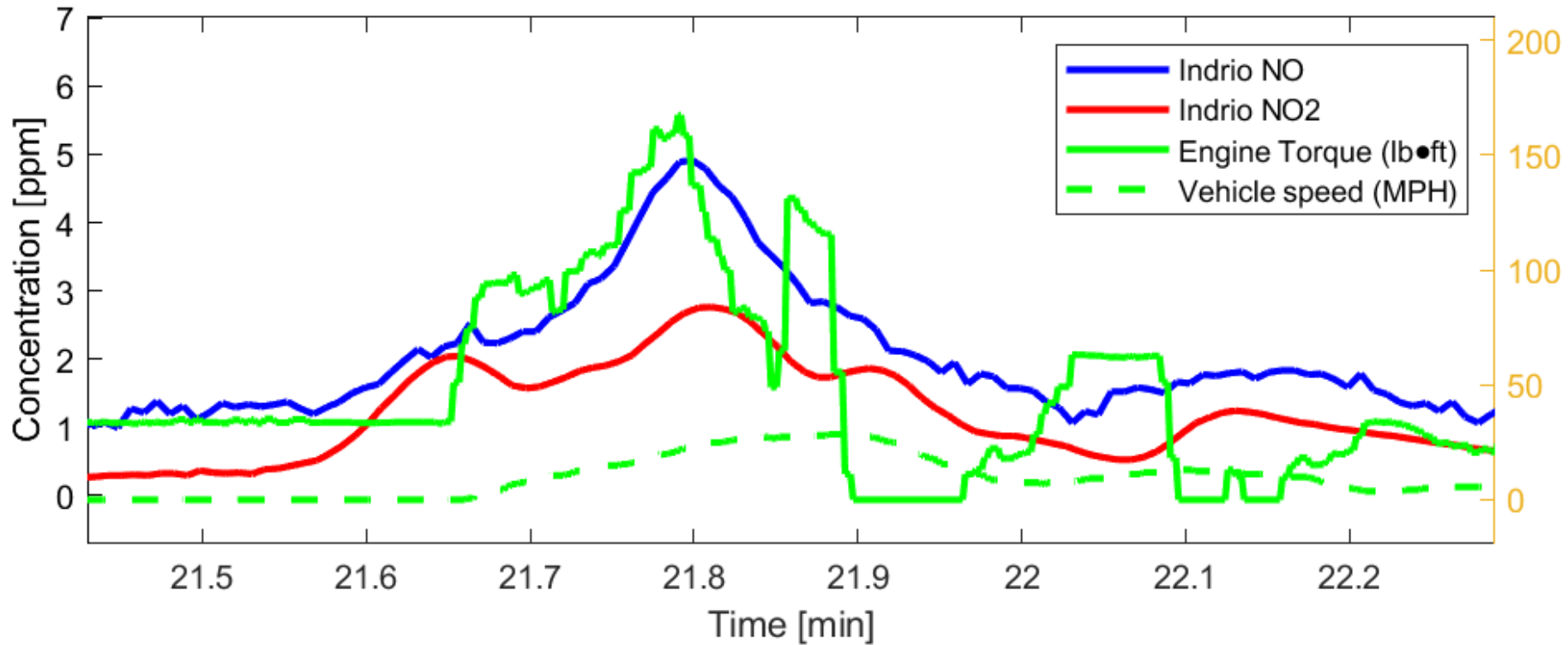
# ZEPHYR NO + NO<sub>2</sub> MEASURED ALONGSIDE OBD NO<sub>x</sub>

- OBD NO<sub>x</sub> sensor is sensitive to NO<sub>x</sub> and ammonia
- OBD NO<sub>x</sub> concentrations above NO and NO<sub>2</sub> without torque strongly suggests ammonia slip



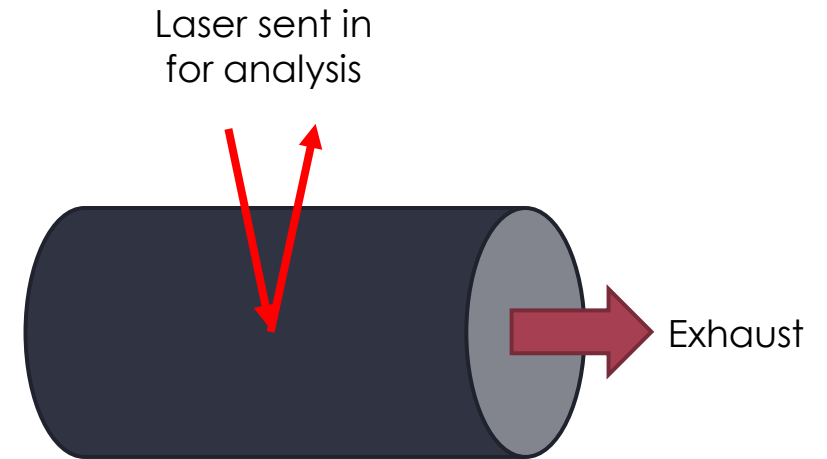
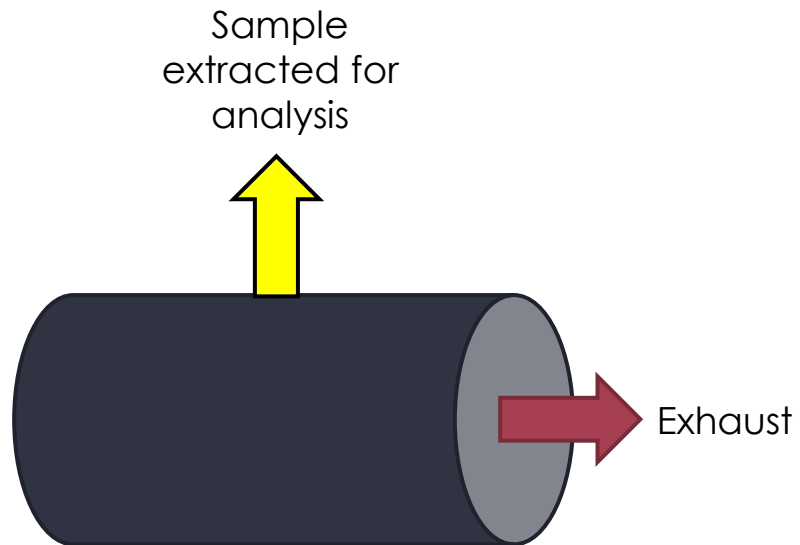
# CORRELATION WITH TORQUE

- Turn-key real-world driving analysis with real-time torque, speed, GPS, gas consumption, catalyst temperature and other parameters

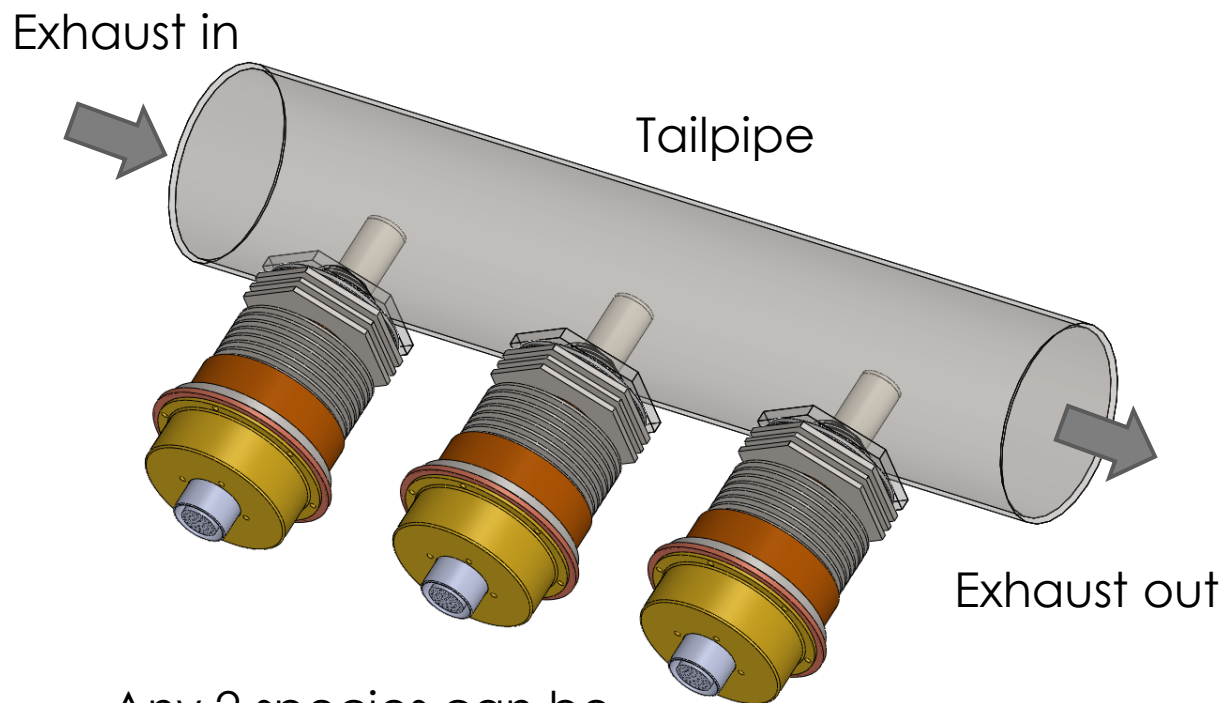


# CORE IN-EXHAUST LASER SENSOR CONCEPT - IGNIS

**Traditional laser-based sensors (PEMS)    Ignis sensors from Indrio (PEMS/future OBM)**



# IGNIS (IN-SITU PEMS)



Detection range:

NO: 0.9 ppm - 1800 ppm

NO<sub>2</sub>: 0.6 ppm - 1200 ppm

N<sub>2</sub>O: 0.15 ppm - 300 ppm

NH<sub>3</sub>: 0.6 ppm - 1200 ppm

Time Resolution: >5Hz

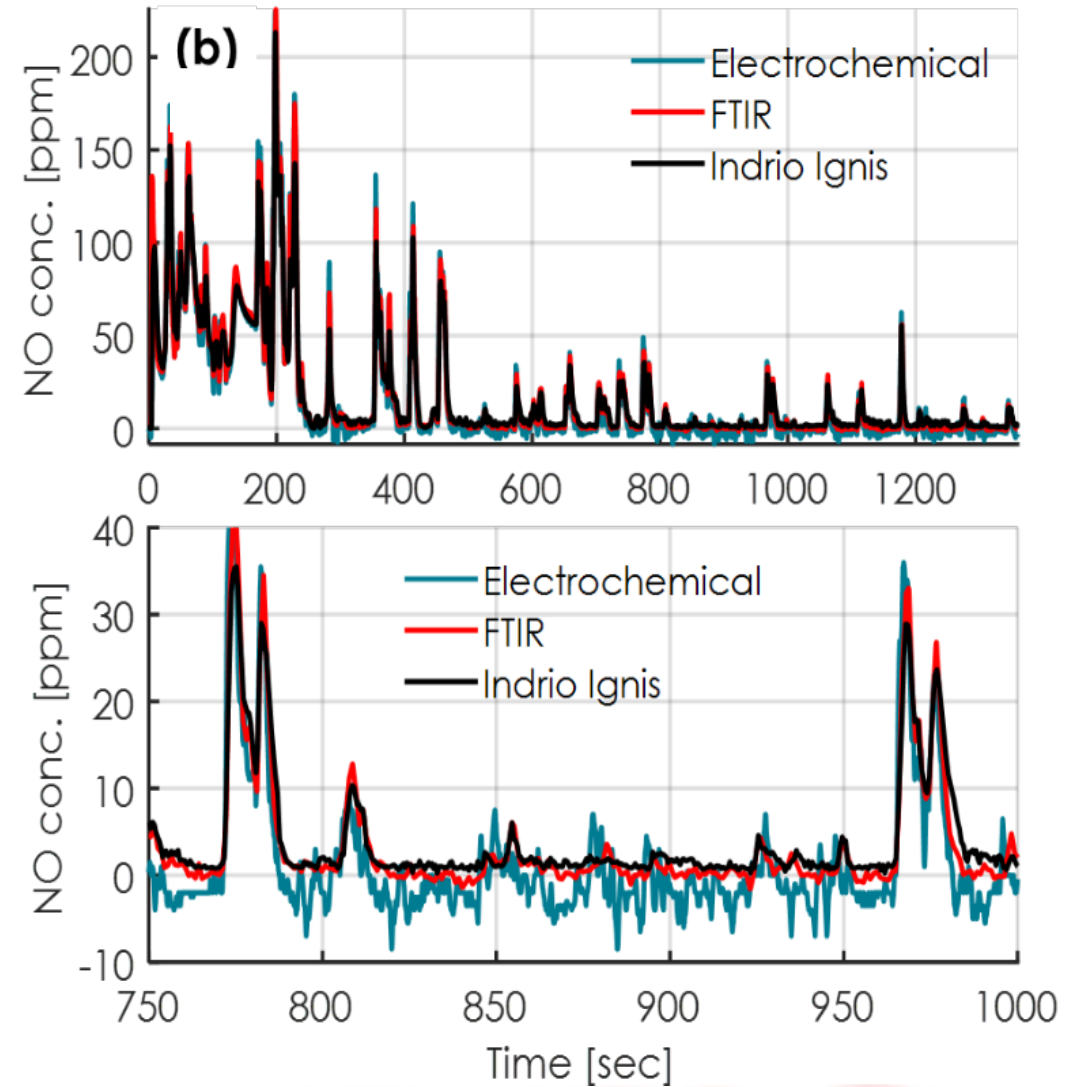
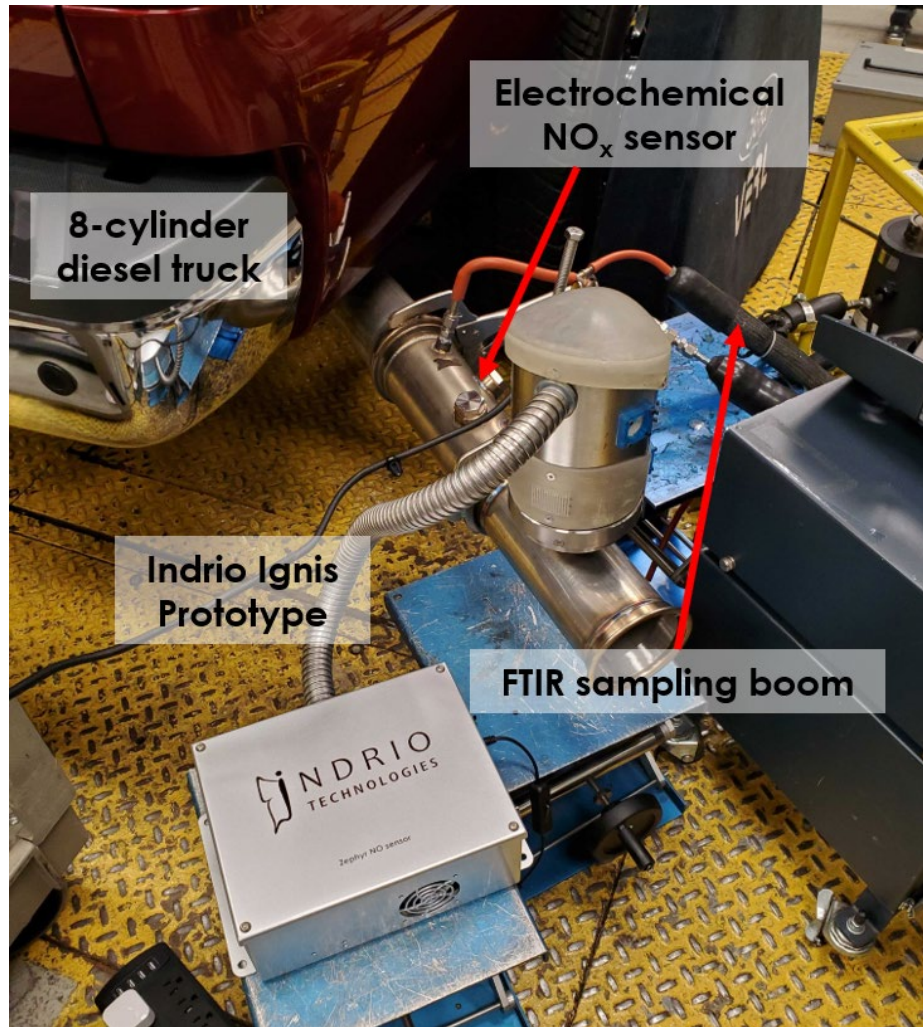
In-situ probe max temp: 600°C

Any 2 species can be  
combined in 1 head

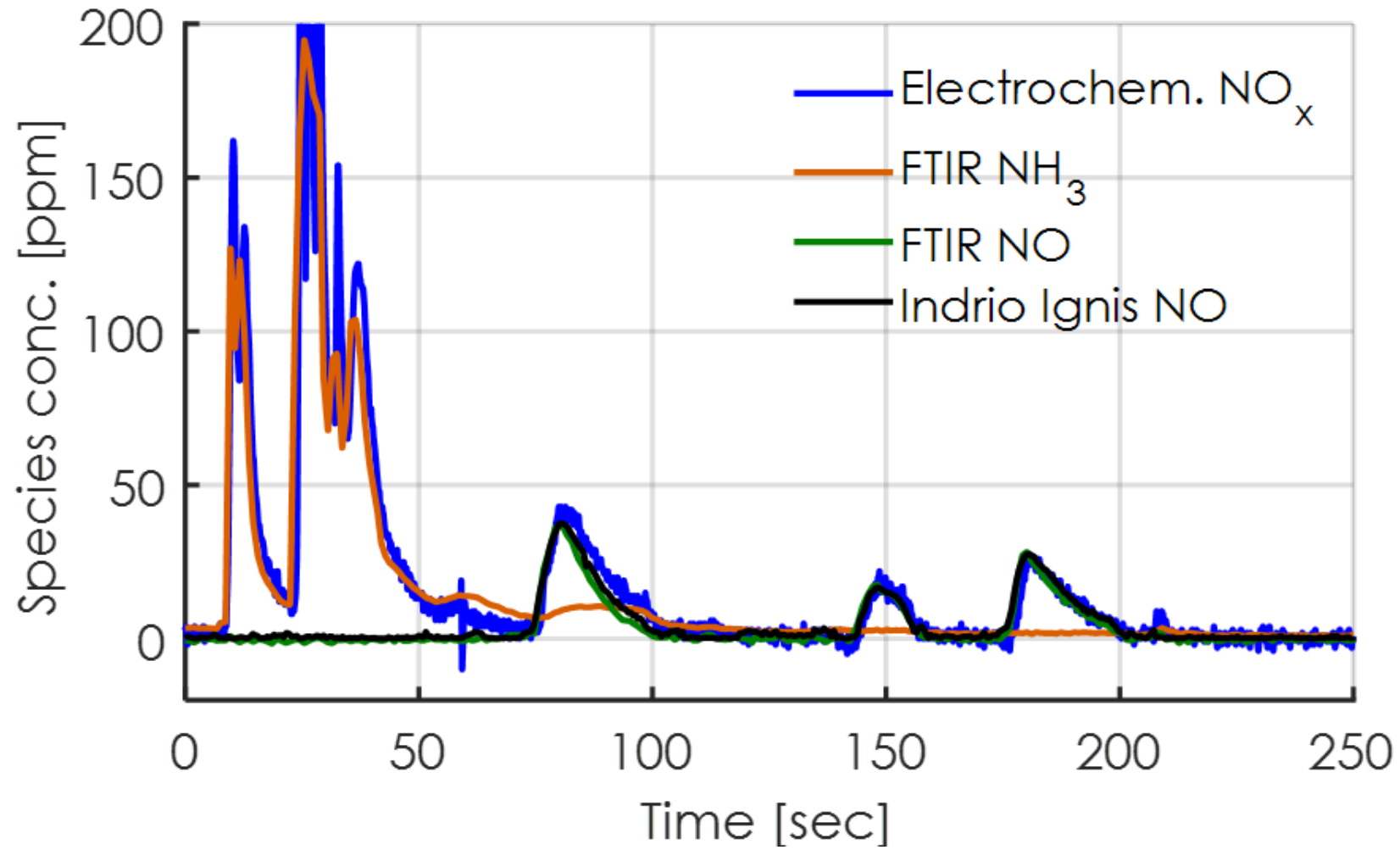
Sensor controller box  
2 species per box



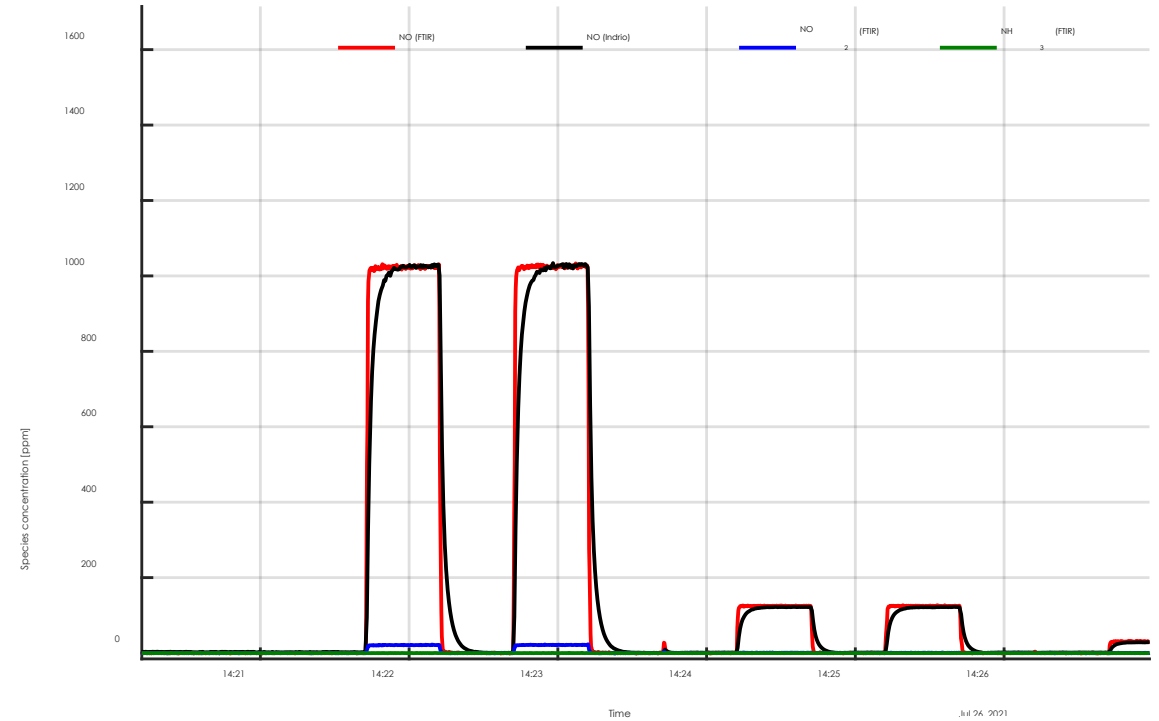
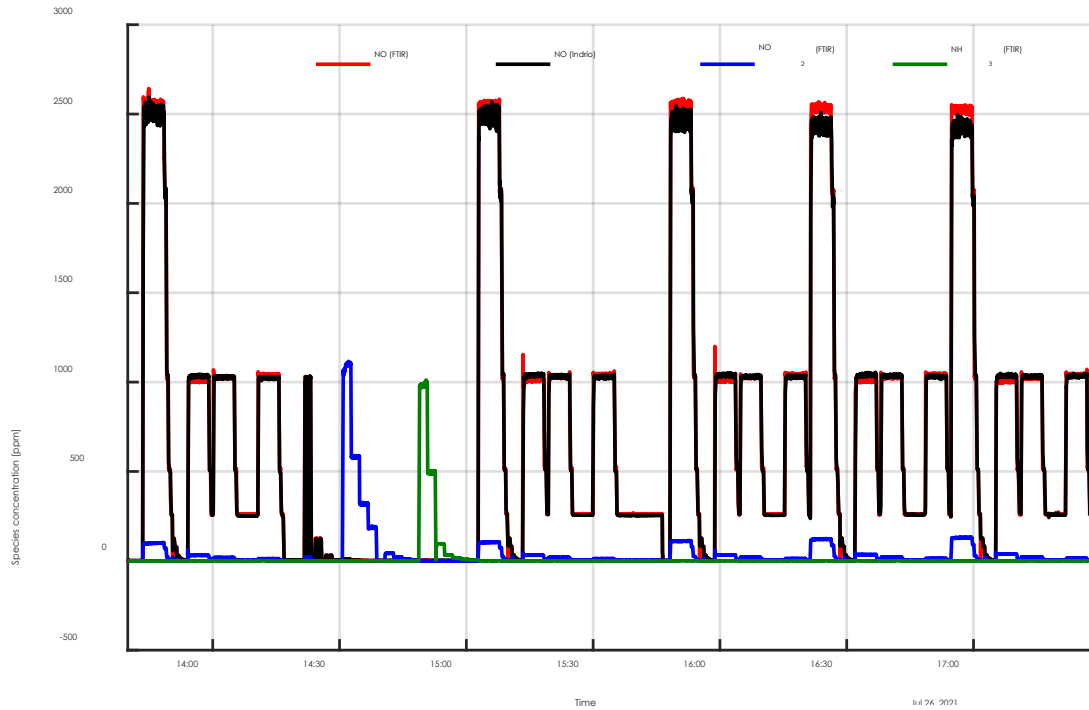
# TESTS AT VEHICLE EMISSIONS RESEARCH LABORATORY (FORD)



# ZERO AMMONIA INTERFERENCE

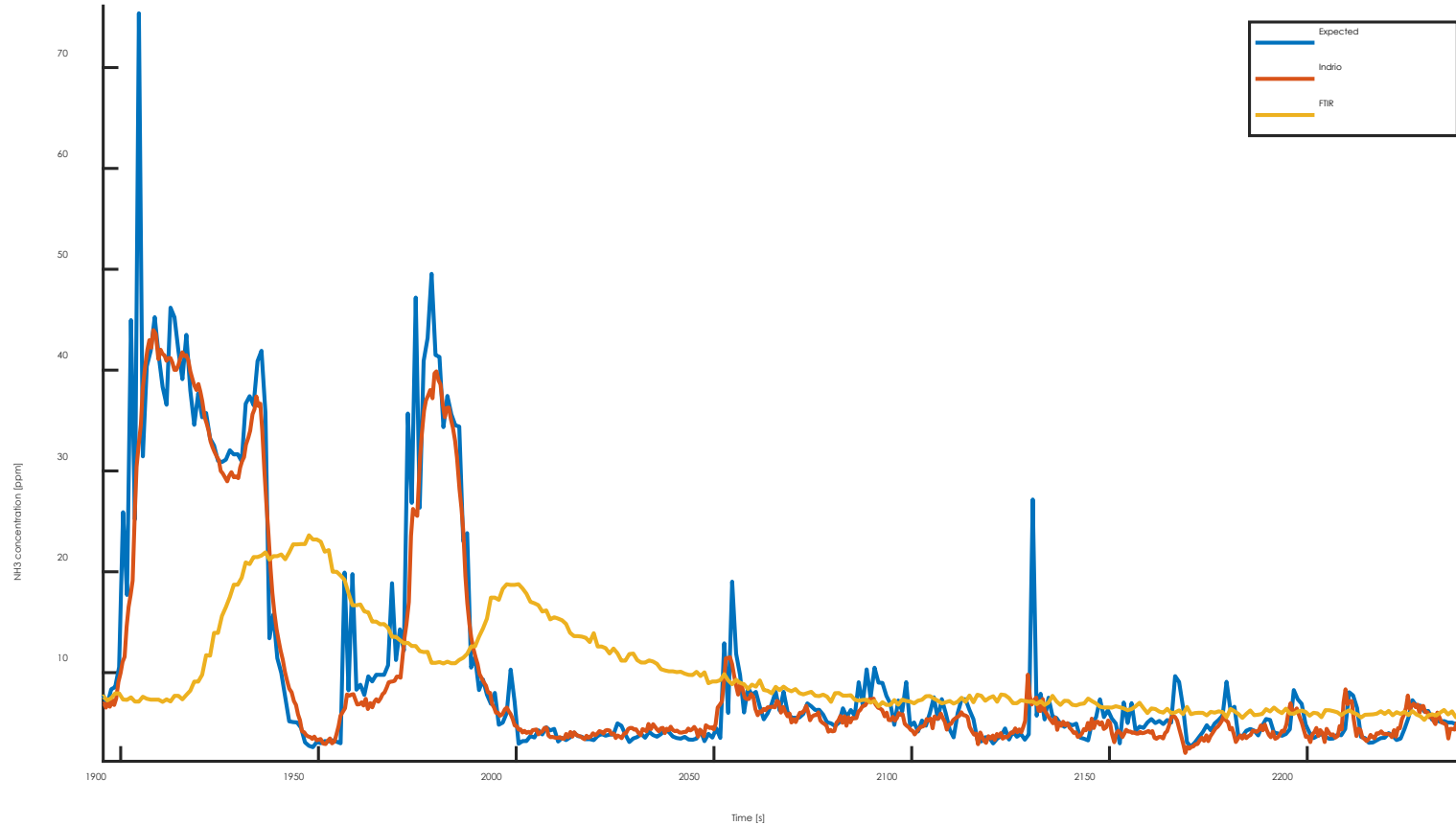


# MORE LAB TEST RESULTS



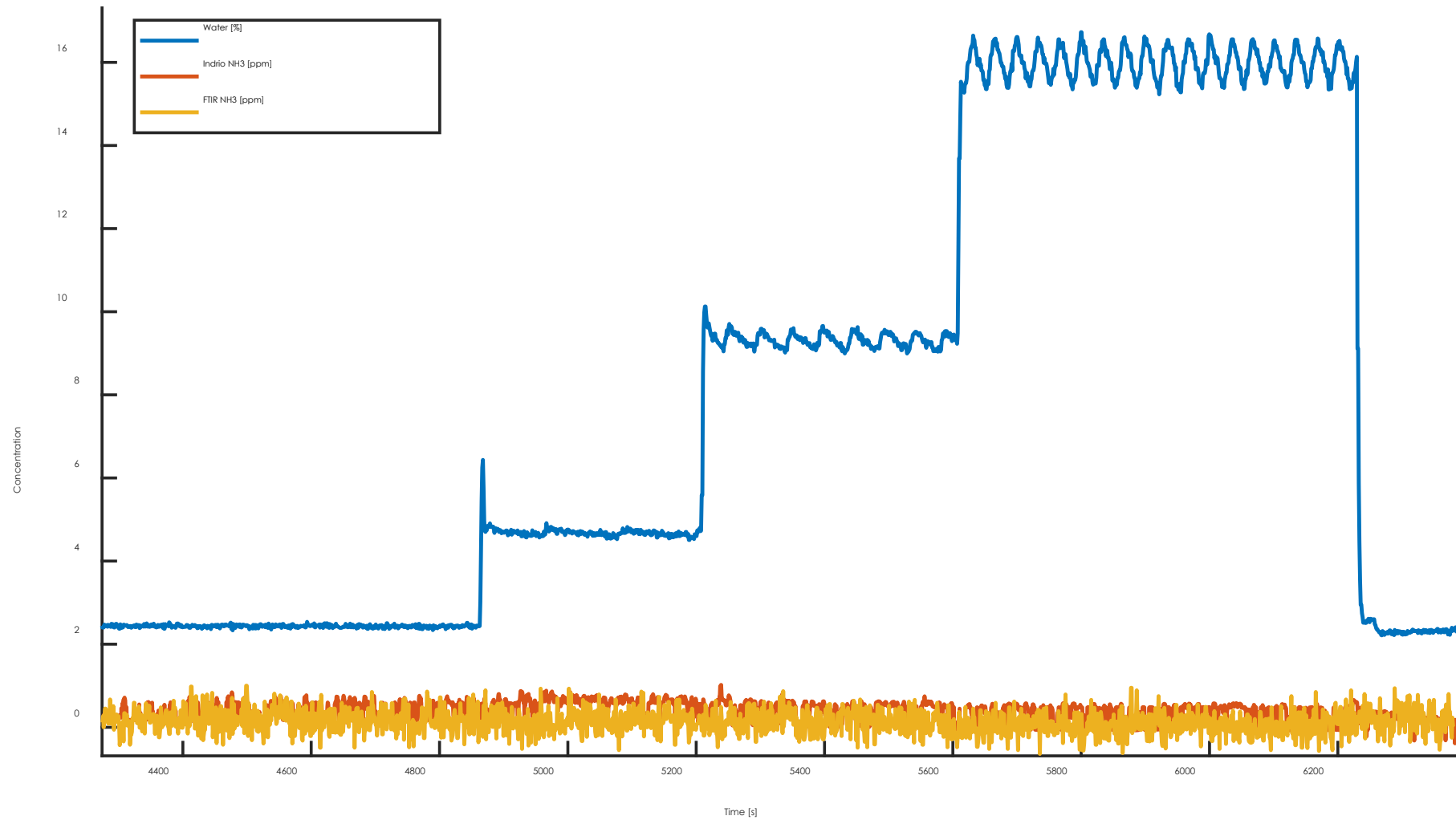
- Results agreed well with lab instrumentation
- 1.5 sec time response (<5 sec required for lab instruments)

# AMMONIA MEASUREMENTS AT ECTO LAB (SWRI)

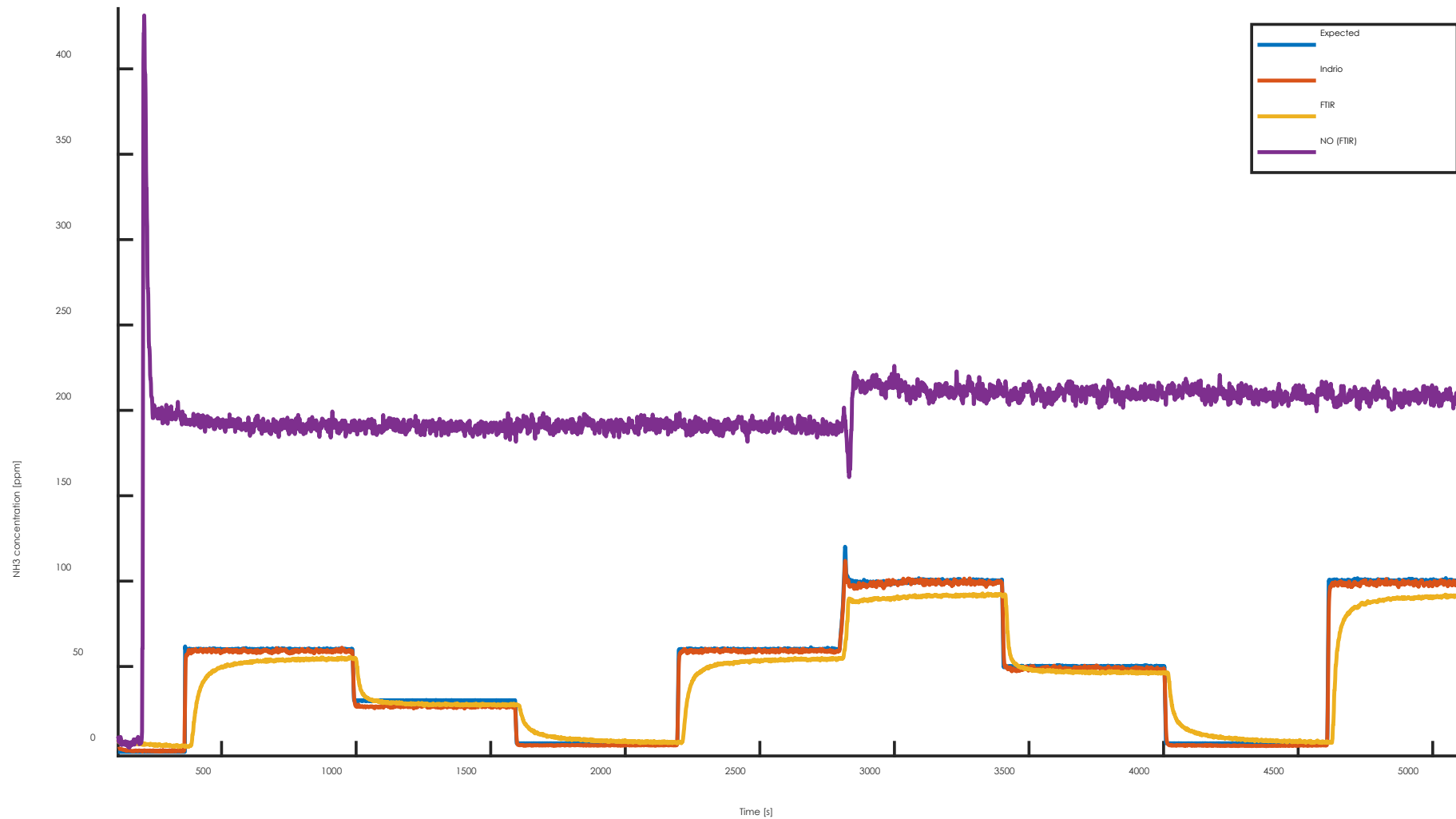


**Indrio's Ignis sensors can track transients significantly better than FTIR**

# ZERO WATER INTERFERENCE



# ZERO NOX INTERFERENCE

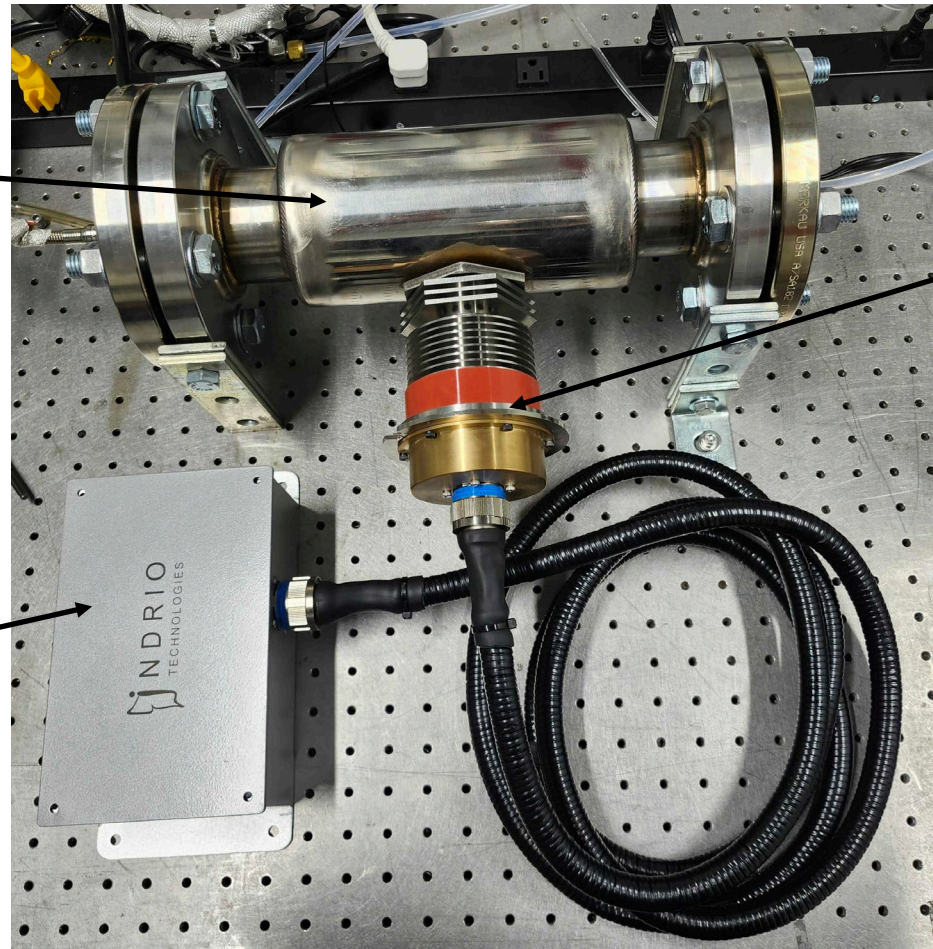


# NEXT STEPS: OSAR DEMONSTRATION

Simulated  
Exhaust Pipe

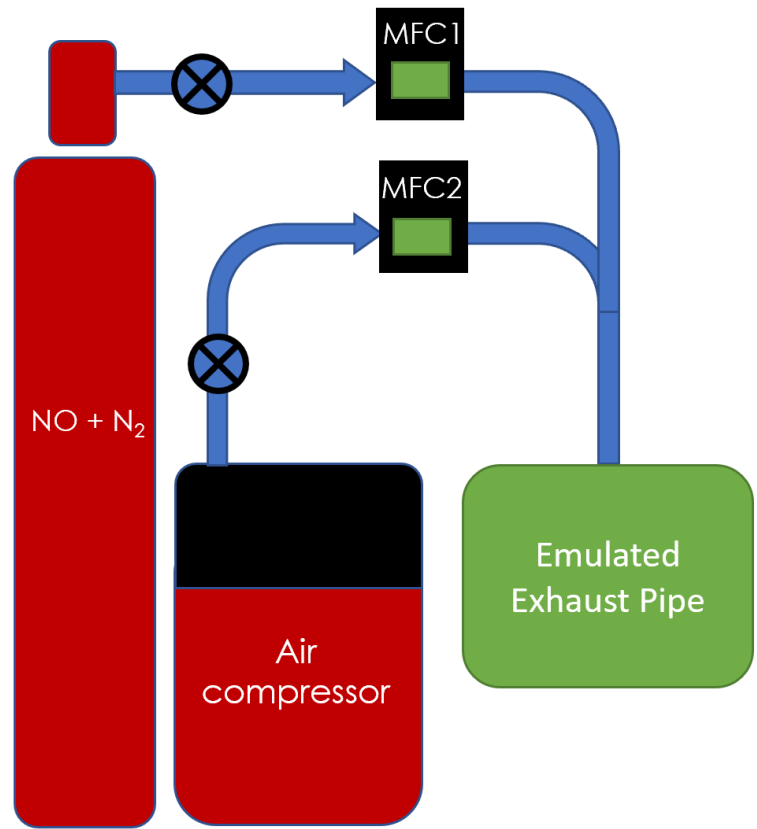
Ignis

Sensor  
control box



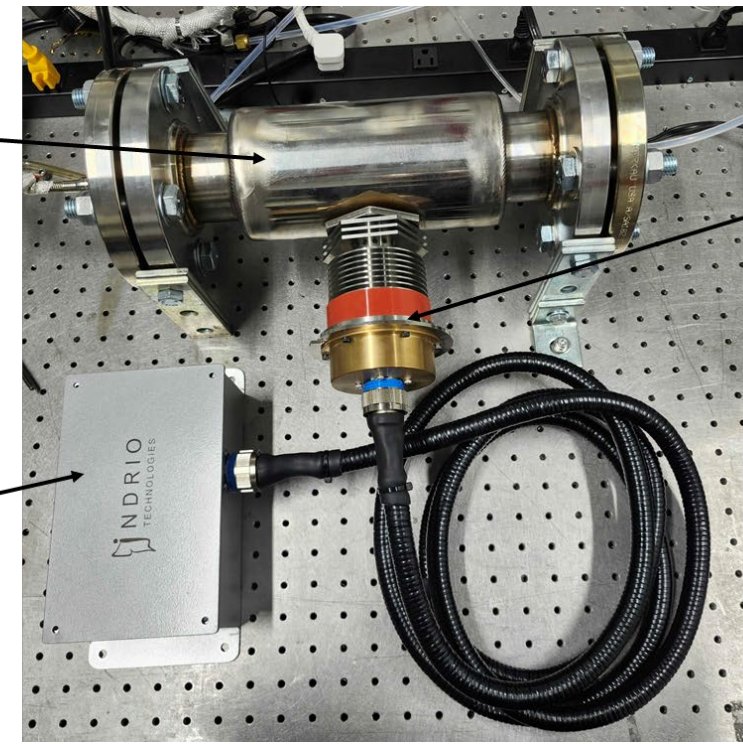
First delivery date:  
**End of this week!**

# IGNIS – PRELIMINARY RESULTS



Simulated Exhaust Pipe

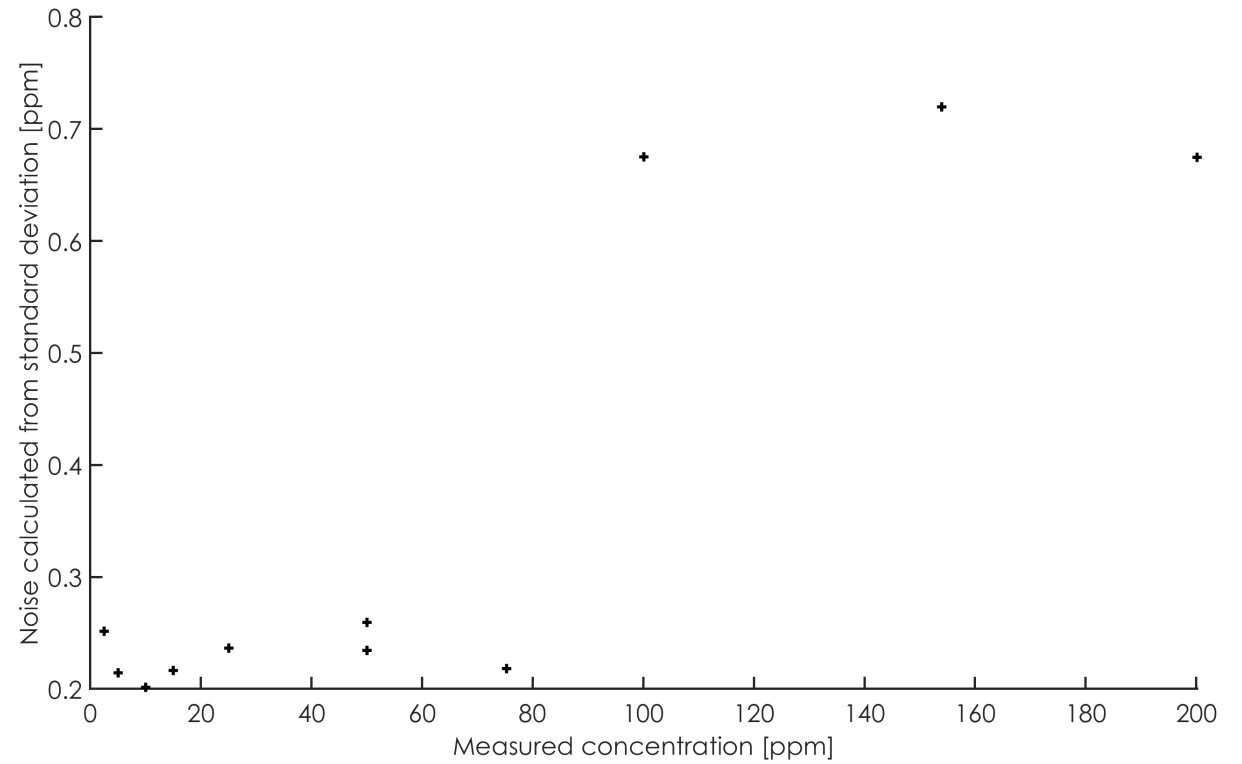
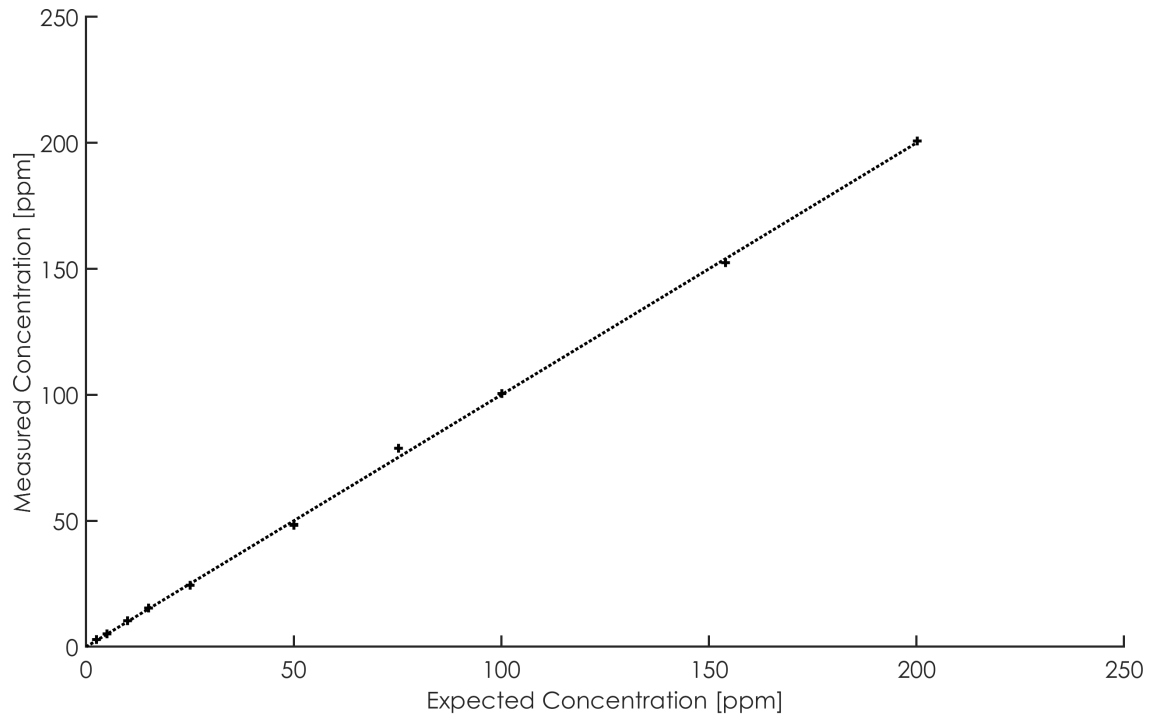
Sensor control box



Ignis



# IGNIS – PRELIMINARY RESULTS



# ACKNOWLEDGEMENTS

- Indrio team
- UCR, CE-CERT
- Cummins
- VERL, Ford Motor Company
- Emissions Research, SWRI
- California Air Resources Board
- Partners at other OEMs
- NSF SBIR funding
- DOE SBIR funding
- Seed Investors

# SPEAKER INFORMATION

Thank you!

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