

# Impurity Analysis and Process Monitoring in Pure CO<sub>2</sub> with Cavity Ring-Down Spectroscopy

Tam Lieu, Florian Adler, and Yu Chen

**Tiger**optics  
High-Performance Gas Analyzers

# Tiger Optics Profile



## Established Company

- Pioneered CRDS in 2001
- 40+ employees
- 100% U.S.-based manufacturing



## Global Customers

- Thousands of installations worldwide
- Global network of distributors



## Customer Satisfaction

More than 70% of sales go to repeat customers



## Certified Technology

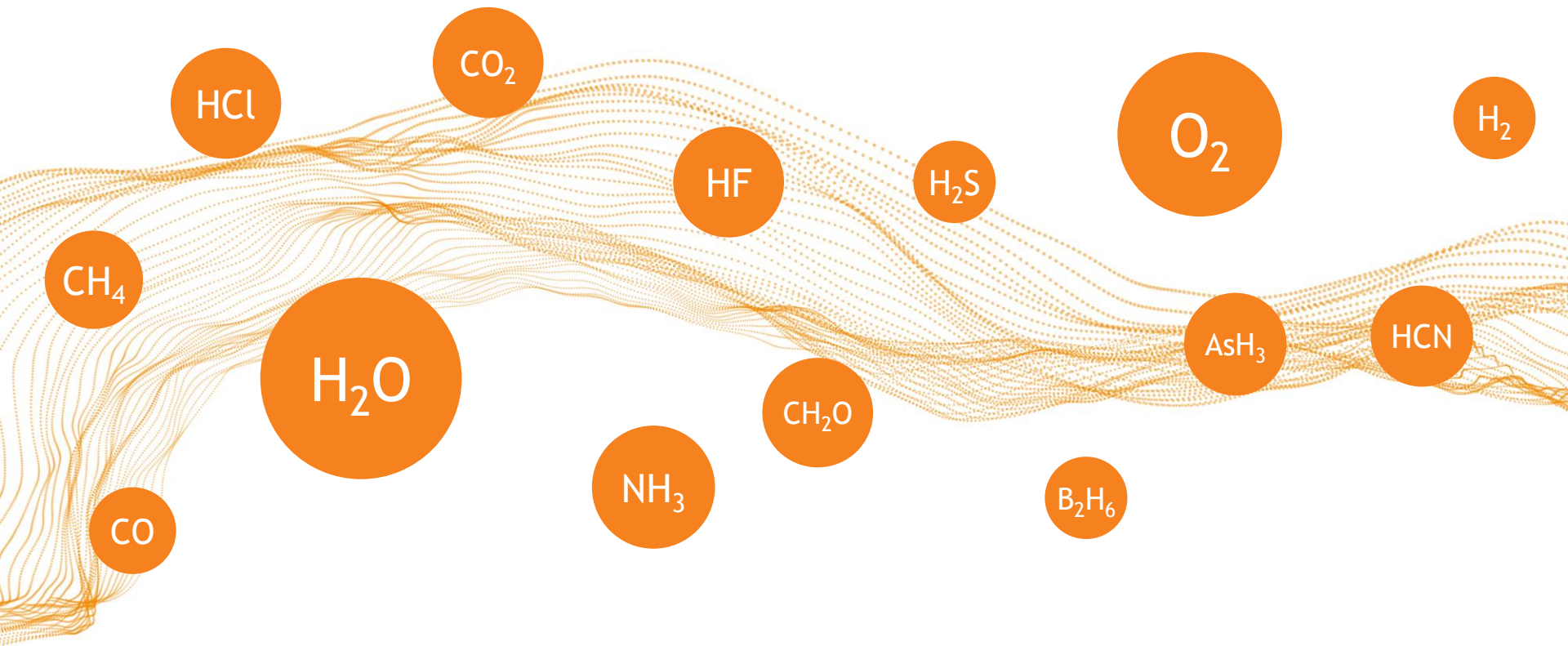
ISO 9001 certification since 2008

Part of Process Insights Holdings since 2018



# What Can We Detect?

Extensive Analysis Capability from PPT to % Levels



# Where Can We Detect?

## Compatibility with a Large Array of Background Gases



Inert & Passive Gases

$N_2$

$H_2$

Ar

He

Ne

Kr

Xe



Oxygenated Gases

$O_2$

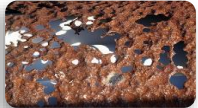
CDA

CO

$CO_2$

$N_2O$

NO



Corrosives

$Cl_2$

HCl

HBr



Hydrides

$NH_3$

$PH_3$

$AsH_3$

$GeH_4$

$SeH_2$



Fluorinated Gases

$SF_6$

$NF_3$

$BF_3$

$C_xF_y$



Various Mixtures (*stack gas, Syngas, ambient air etc.*)

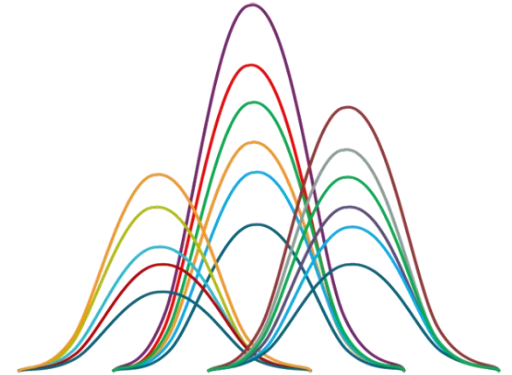
# Advantages of Tiger's CRDS Technology



**Unparalleled Sensitivity**



**Absolute Measurement  
No Calibration Needed**



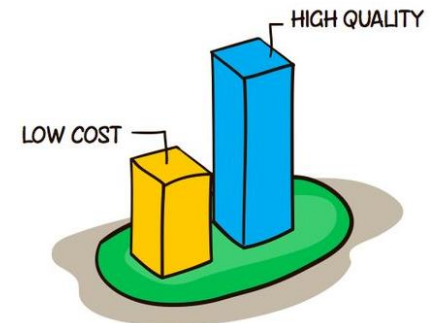
**Intrinsically Linear  
Wide Dynamic Range**



**Non-contact Measurement  
Fast Speed of Response**

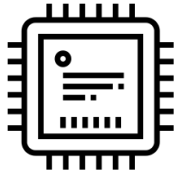


**High Specificity &  
Versatility**



**Exceptionally Low  
Cost of Ownership**

# CO<sub>2</sub> Matrix: Selected Applications & Markets



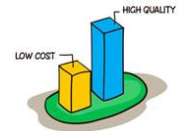
## Semiconductor/Purifier Makers

- Trace O<sub>2</sub> in electronic grade UHP CO<sub>2</sub>
- Photolithography



## Beverage

- PPM level H<sub>2</sub>O and NH<sub>3</sub>
- Process control guideline species



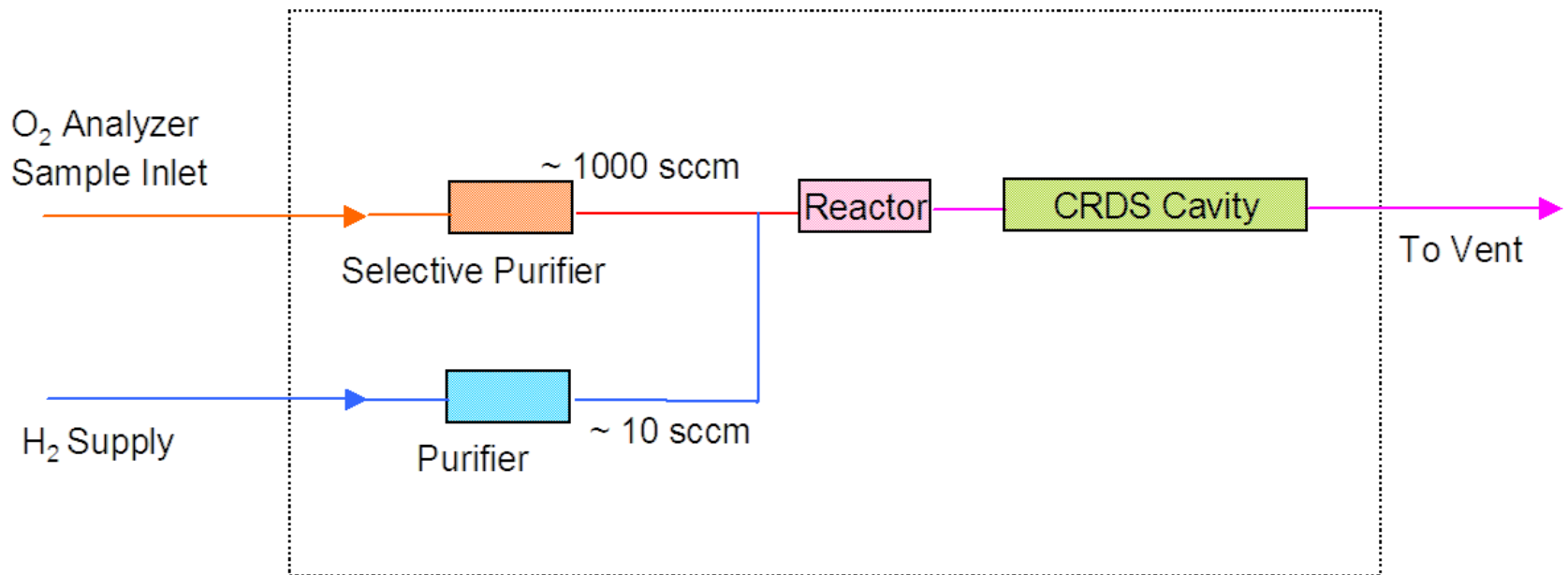
## Gases & Chemicals

- Trace HCl in product CO<sub>2</sub>
- CO<sub>2</sub> gas manufacturing, purification, and liquefaction plants



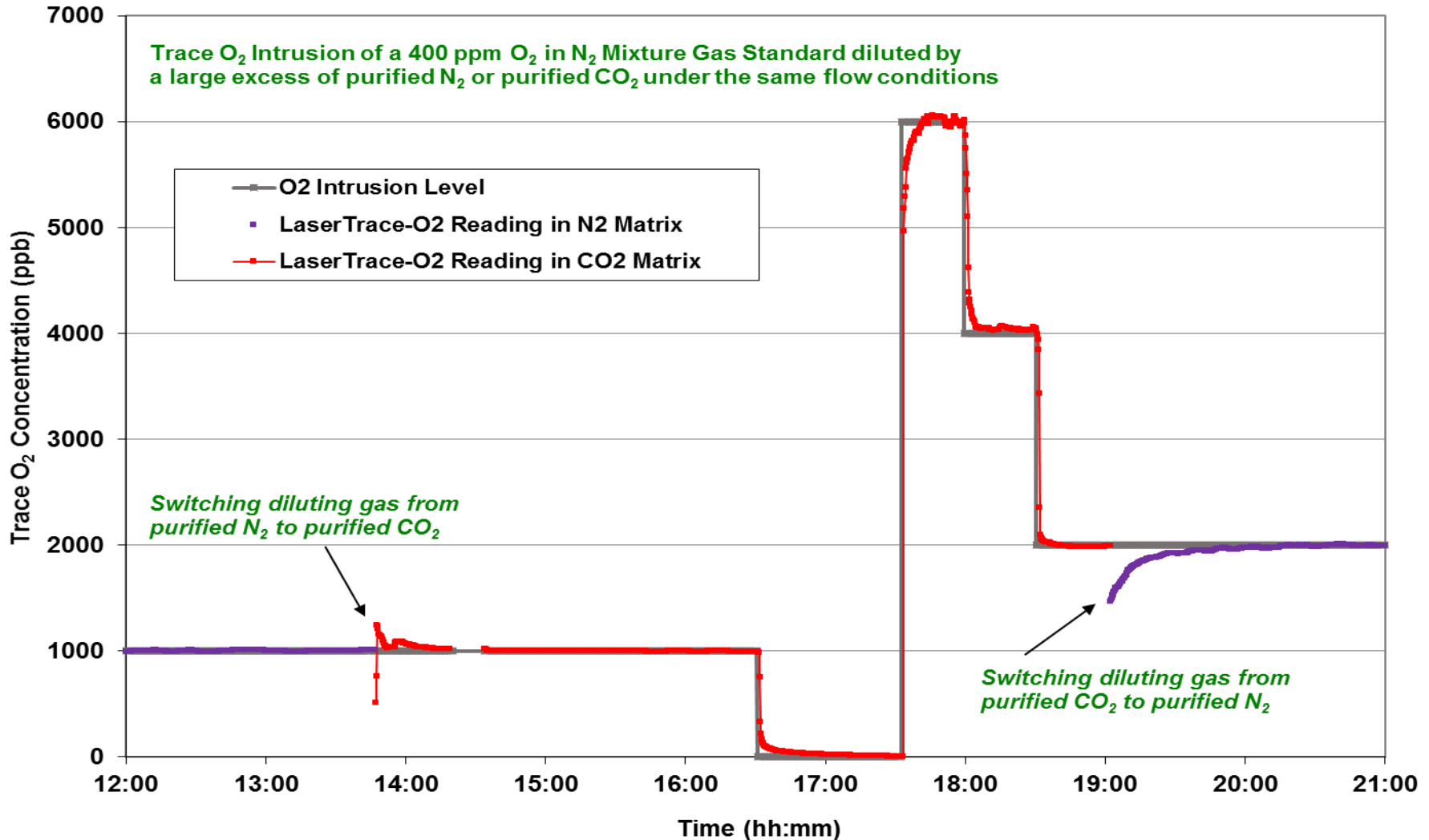
# Trace O<sub>2</sub> in Electronic Grade UHP CO<sub>2</sub>

Fast, quantitative conversion of trace oxygen to water\*



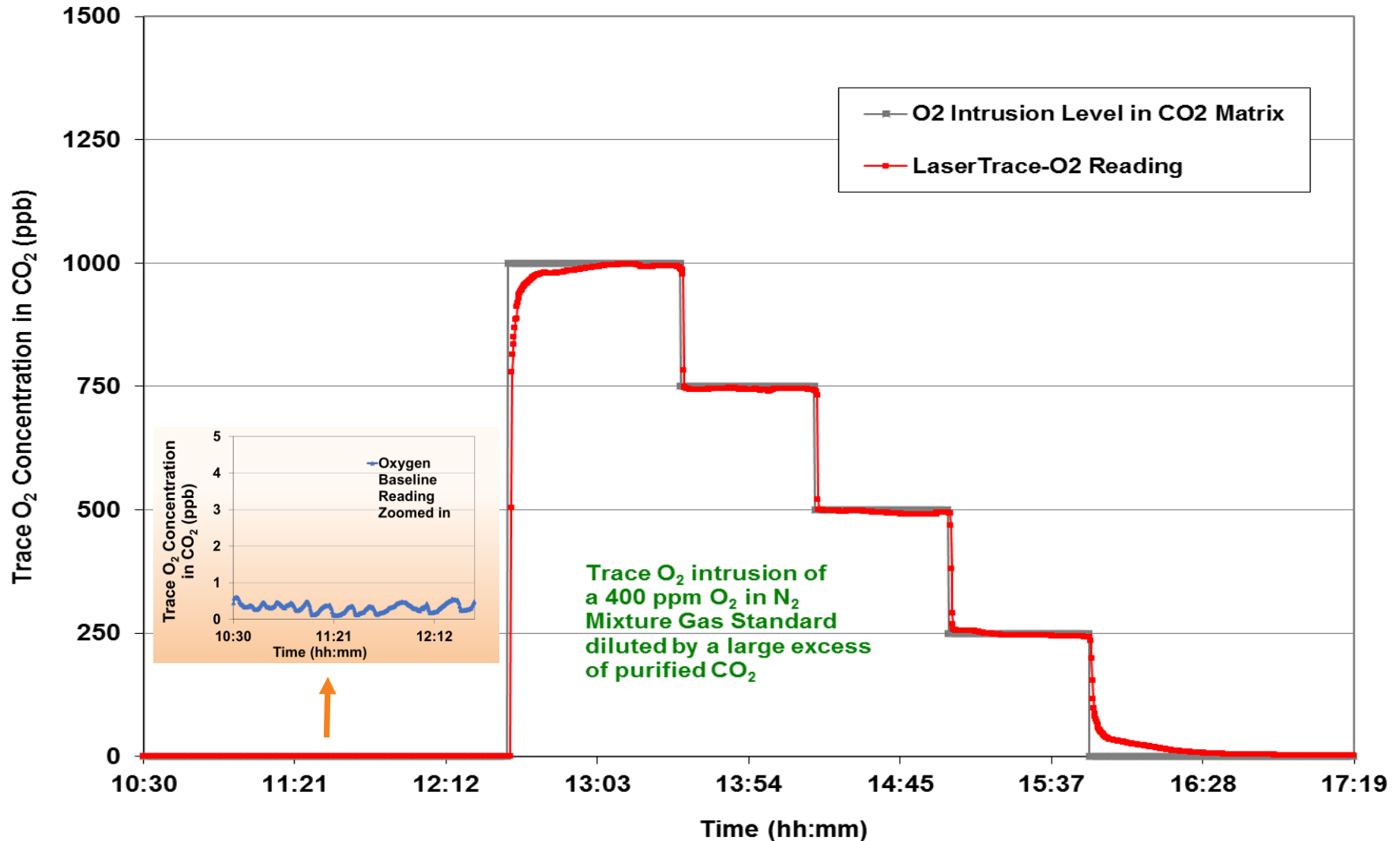
\*U. S. Patent # 7,255,836—Lehmann KK, et al.

# Trace O<sub>2</sub> in Electronic Grade UHP CO<sub>2</sub>

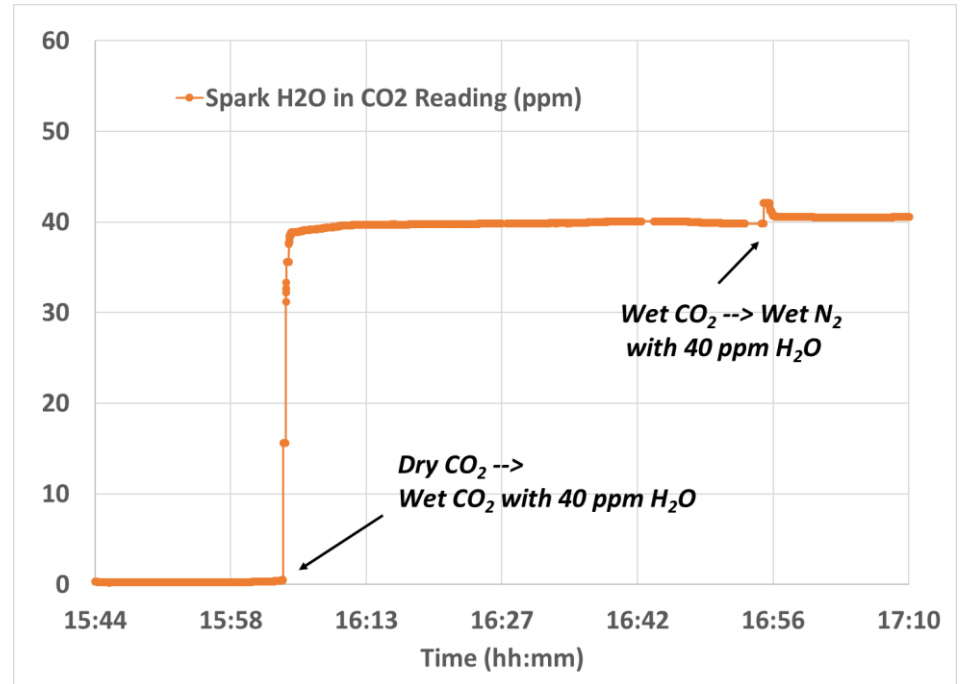




# Trace O<sub>2</sub> in Electronic Grade UHP CO<sub>2</sub>



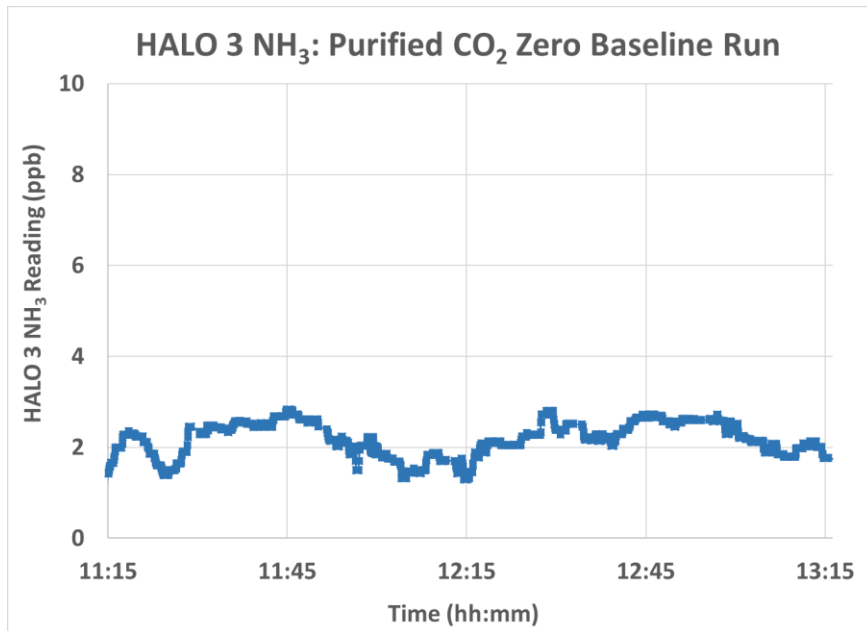
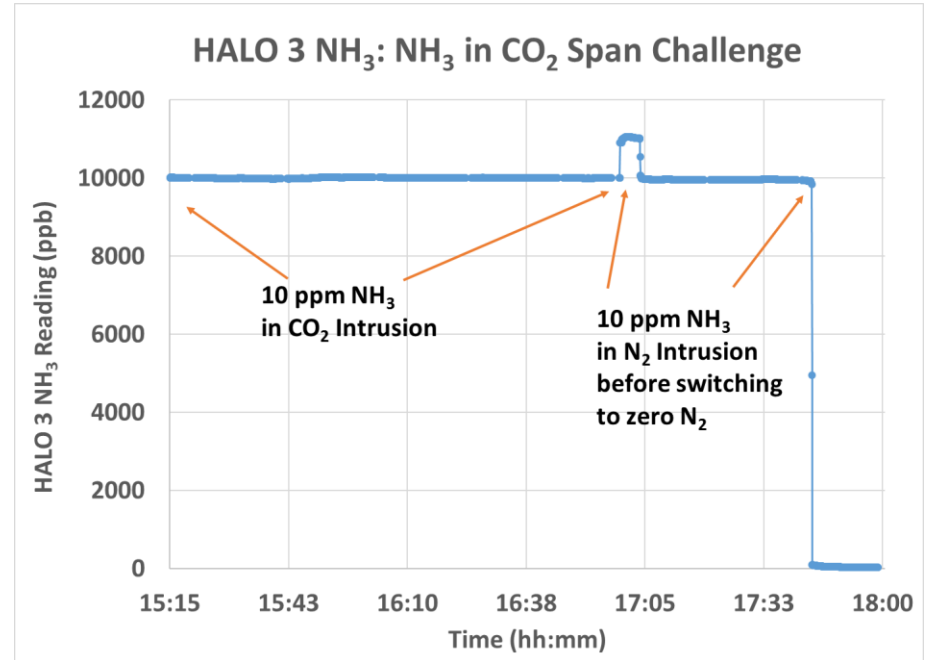
# Trace H<sub>2</sub>O: A Key Guideline Species in Beverage CO<sub>2</sub>



Parameter		Rationale <sup>1</sup>
Purity	99.9% v/v min.	Process
Moisture	20 ppm v/v max.	Process
Acidity	To pass test	Regulatory
Oxygen	30 ppm v/v max.	Sensory
Nitrogen compounds		
Ammonia	2.5 ppm v/v max.	Process
Nitric oxide/nitrogen dioxide	2.5 ppm v/v max. each	Regulatory

ISBT (*International Society of Beverage Technologists*)  
Carbon Dioxide Guidelines

# Trace NH<sub>3</sub>: A Key Guideline Species in Beverage CO<sub>2</sub>



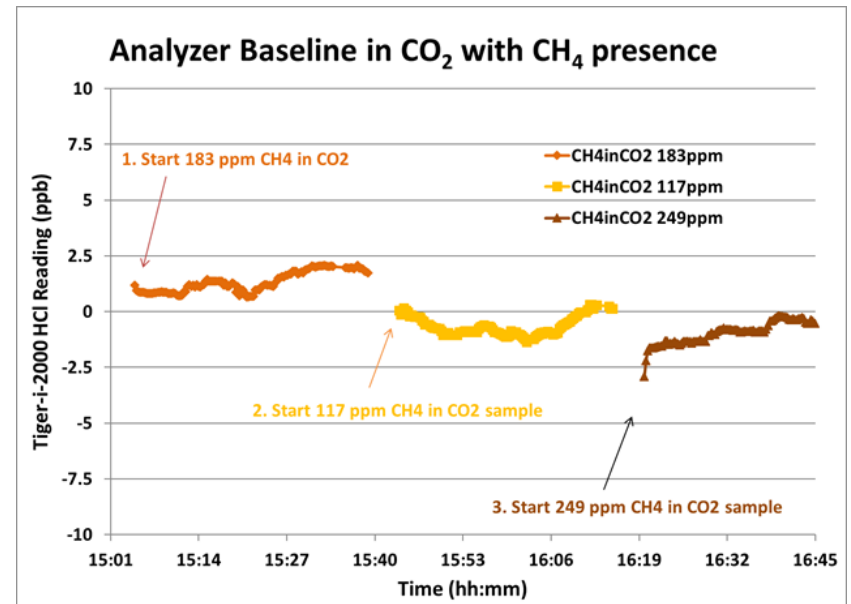
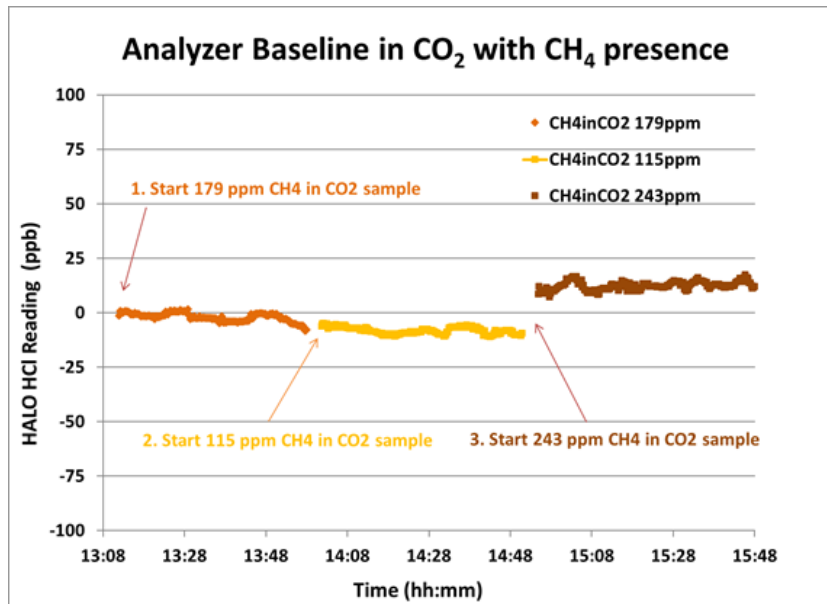
ISBT (*International Society of Beverage Technologists*)  
Carbon Dioxide Guideline:  
Ammonia 2.5 ppm v/v max.

# HCl in Product CO<sub>2</sub> Pre and Post Chloride Adsorber

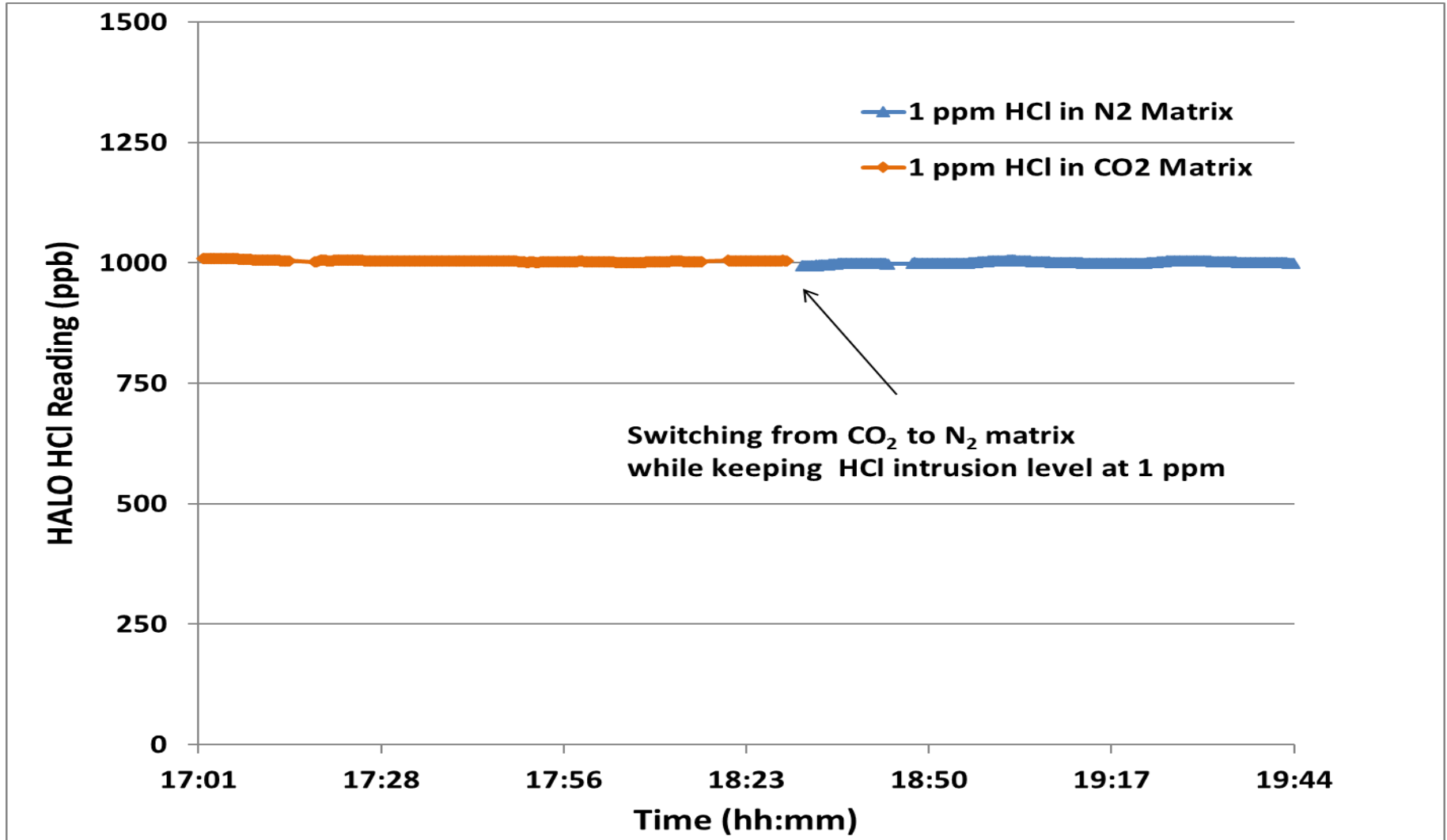
- Application LDL/Range: 50 ppb/10 ppm
- LDL Limiting Factor: CH<sub>4</sub> @ 115 - 243 ppm



- Application LDL/Range: 5 ppb/4 ppm
- LDL Limiting Factor: CH<sub>4</sub> @ 117 - 249 ppm



# HCl in CO<sub>2</sub> Span Calibration Test



# Tiger CRDS Measurement Capability in Pure CO<sub>2</sub>

Analyte	LDL	Range	Industry/Application
O <sub>2</sub>	5 ppb	5 ppm	Electronics/Photolithography/Purifier Maker
H <sub>2</sub> O	0.8 ppb	25 ppm	Electronics/Photolithography/Purifier Maker
H <sub>2</sub> O	0.6 ppm	600 ppm	Beverage/Gas Manufacturing
H <sub>2</sub> O	5 ppm	2%	Nuclear Industry/coolant CO <sub>2</sub>
NH <sub>3</sub>	2.5 ppb	30 ppm	Beverage/Gas Manufacture
HCl	5 ppb	4 ppm	Gas Manufacturing Post Chloride Adsorber
HCl	50 ppb	10 ppm	Gas Manufacturing Pre Chloride Adsorber
H <sub>2</sub> S	0.1 ppm*	500 ppm	Beverage/Gas Manufacture
CO	0.4 ppm*	3000 ppm	Beverage/Gas Manufacture
CH <sub>4</sub>	0.1 ppm*	500 ppm	Beverage/Gas Manufacture
HF	0.5 ppb*	1 ppm	Multiple
N <sub>2</sub> O	0.1 ppm*	1000 ppm	Multiple

\*Subject to development testing

# Summary



- CO<sub>2</sub> is an important gas matrix used in a diverse range of industries, from semiconductor and purifier makers, to beverage, as well as gases & chemicals
- Tiger CRDS can detect critical impurities in pure CO<sub>2</sub>, such as O<sub>2</sub>, H<sub>2</sub>O, NH<sub>3</sub> & HCl, over a wide concentration range in various process control scenarios
- An innovative partner with customers in addressing challenging, real-world applications, Tiger looks forward to more exciting, new developments