Advanced Spectroscopic Solutions for Fuel Cell Hydrogen Analysis

GASES & CHEMICALS | CEMS | ENERGY | ATMOSPHERIC | SEMI & HB LED | SYNGAS | LAB & LIFE SCIENCE

Tiger Optics' portfolio of CRDS-based analyzers for analysis of fuel-cell-grade hydrogen offers:

- Absolute accuracy due to time-based Cavity Ring-Down Spectroscopy (CRDS)
- Analysis of multiple critical contaminants listed in hydrogen purity standards SAE J2719 or ISO 14687: H_2O, CH_4, CO, CO_2, NH_3, CH_2O and O_2
- Part-per-billion (ppb) detection limits, range up to thousands of parts-per-million (ppm)
- Freedom from the need for span calibrations
- No periodic sensor replacement/maintenance
- Drift-free performance
- Designed to comply with ASTM Standard Test Method D7941 for fuel cell hydrogen analysis

The Easy Way to Ensure Hydrogen Quality

Hydrogen quality is critical for the performance and lifetime of hydrogen fuel cells. H_2O, CH_4, CO, CO_2, NH_3, CH_2O and O_2 are severe contaminants for this application, causing performance reduction, degradation of the proton exchange membrane, and damage to the catalyst. Tiger Optics offers powerful analytical tools for the measurement of trace amounts of these molecules. The instruments' ppb-level detection limits help ensure compliance with SAE J2719, ISO 14687 and similar purity standards to protect fuel cell electric vehicles (FCEVs) from damage.

Based on powerful Cavity Ring-Down Spectroscopy (CRDS), with a proprietary laser-lock cell, all Tiger analyzers are free of drift, guaranteeing consistent and reliable trace detection for fuel-cell-grade hydrogen in the lab or in the field. Highly specific to the target molecule, CRDS also eliminates measurement distortion from cross-interference. Plus, there is no need to perform costly and time-consuming zero and span calibrations, saving both time and money with continuous, online service.

Tiger Optics offers multiple platforms: the Spark, the HALO 3, the HALO OK, and the Prismatic™ 2 for single-species and multi-species analysis, all optimized to give users robust performance, extremely low Cost of Ownership, and operational simplicity.

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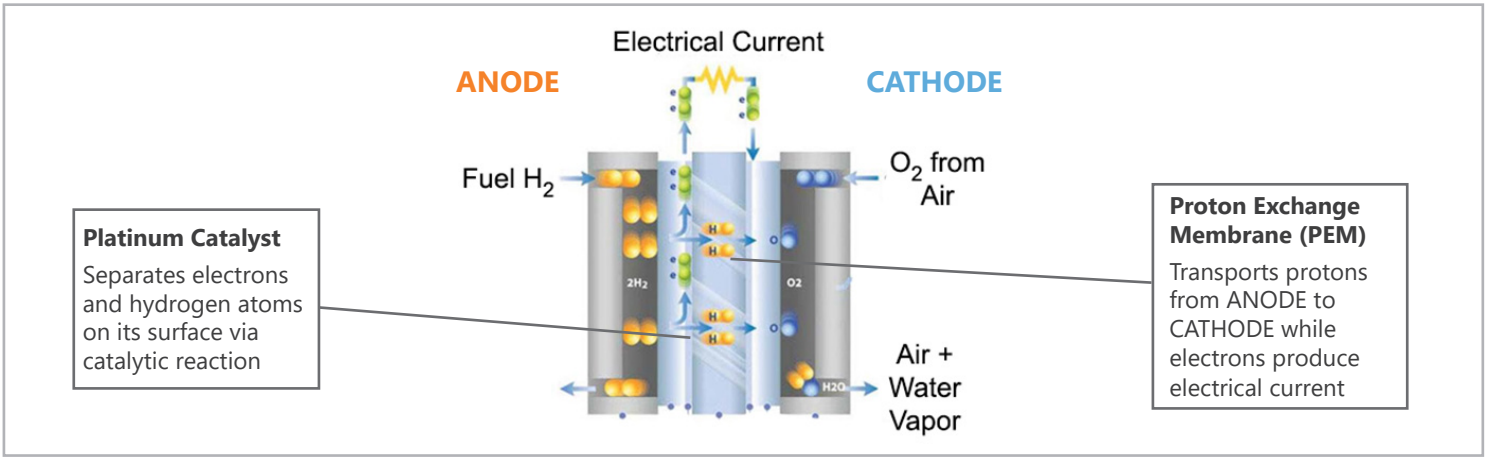
Fuel Cells and Hydrogen Purity

High-purity hydrogen is crucial to the performance and lifetime of fuel cells. The critical componts of the fuel cell are the platinum catalyst and the proton exchange membrane (PEM). Both can experience significant loss in performance or even irrversible damage in the presence of contaminants on the anode side (hydrogen side) of the fuel cell.

Principle of a PEM Hydrogen Fuel Cell used in FCEVs



Effects of Contaminants in Hydrogen on the Fuel Cell Anode

Moisture (H_2O)	Cathode-side molecule, impedes efficiency of fuel-cell reaction ($2H_2 + O_2 \rightarrow H_2O$)
Methane (CH_4)	Degrades performance of catalyst, can accumulate in H_2 recirculation loop
Carbon Monoxide (CO)	Adsorbs onto catalyst and severely degrades performance, difficult to recover
Carbon Dioxide (CO_2)	Reduces to CO and adsorbs to catalyst
Ammonia (NH_3)	Impedes conductivity of membrane, signifcantly affects performance, recoverable
Formaldehyde (CH_2O)	Reacts with catalysts, degrades performance, possible accumulation via H_2 recirculation
Oxygen (O_2)	Cathode-side molecule, impedes efficiency of fuel-cell reaction ($2H_2 + O_2 \rightarrow H_2O$)

Hydrogen Purity and Measurement Standards

Most countries have adopted the fuel cell hydrogen purity standard **SAE J2719**, developed by the **Society of Automotive Engineers**, which sets limits for the species listed above: H_2O, CH_4, CO, CO_2, NH_3, CH_2O and O_2, as well as six other critical contaminants. The purity specifications were also adopted by other standards, for instance, **ISO 14687**.

Tiger Optics has worked with **ASTM International** to create a standard test method for the analysis of fuel-cell grade hydrogen using CW-CRDS to allow users to take advantage of this powerful analytical method for this application. The standard was finalized in 2014 and is designated as **ASTM D7941/D7941M-14**.

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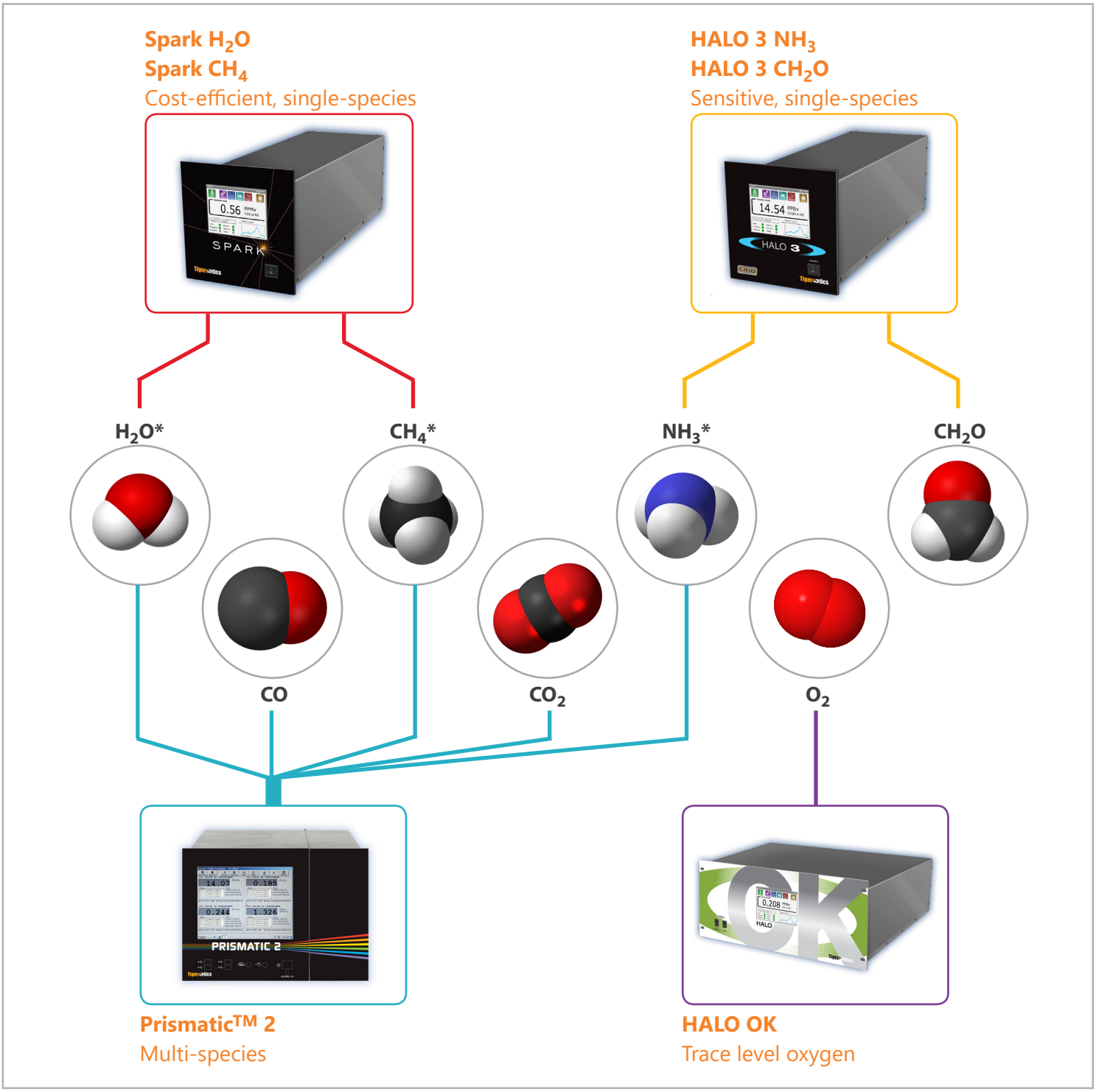
Products for H_2 Purity Analysis

Tiger Optics offers four different versatile CRDS platforms for single-species or multi-species detection of critical impurites in fuel-cell-grade hydrogen to assure **SAE J2719/ISO 14687 compliance**. All of Tiger Optics' systems are also optimized for H_2 analysis according to **ASTM Standard Test Method D7941**.



*For **H_2O**, **CH_4** and **NH_3** detection, you can choose between dedicated single-species analyzers (**Spark** and **HALO 3**, respectively) or the multi-species **Prismatic 2**. The **Prismatic 2** can be configured to detect a maximum of four different molecules. The recommended analyzer combination depends on your requirements. Please contact us to discuss your optimum solution.

Spark H_2O
Spark CH_4
Trace Level Analyzers for Moisture and Methane

Performance in H_2	
Operating range	See table below
Detection limit (MDL)*	See table below
(95% confidence limit)	
SAE J2719 Limit	See table below
Precision (1σ, greater of)	± 0.75% or 1/2 of MDL
Accuracy (greater of)	± 4% or MDL
Speed of response	< 3 minutes to 90%
Environmental conditions	10°C to 40°C
	30% to 80% RH (non-condensing)
Storage temperature	-10°C to 50°C

Gas Handling System and Conditions	
Wetted materials	316L stainless steel
	10 Ra surface finish
Gas connections	1/4" male VCR
Inlet pressure	10 – 125 psig (1.7 – 9.6 bara)
Flow rate	~1.4 slpm
Gas temperature	Up to 60°C

Dimensions	H x W x D [in (mm)]
Standard sensor	8.73 x 8.57 x 23.6 (222 x 218 x 599)
Sensor rack	8.73 x 19.0 x 23.6 (222 x 483 x 599)
(fits up to two sensors)	

Weight	
Standard sensor	32 lbs (14.5 kg)

Electrical	
Alarm indicators	2 user programmable
	1 system fault
	Form C relays
Power requirements	90 – 240 VAC, 50/60 Hz
Power consumption	40 Watts max.
Signal output	Isolated 4–20 mA per sensor
User interfaces	5.7" LCD touchscreen
	10/100 Base-T Ethernet
	802.11g Wireless (optional)
	RS-232

Performance in H_2:	Part Number	Range	MDL*	SAE/ISO Limit
Spark H_2O	F7700	0 – 1750 ppm	6 ppb	5000 ppb
Spark CH_4	F7701	0 – 80 ppm	6 ppb	100 ppb†

*Method detection limit (MDL) is determined using U.S. EPA 40 CFR Part 136 Appendix B (95% Confidence Limit)
†Concentration limit when using CH_4 measurement instead of total hydrocarbon (THC) analysis (total THC limit is 2 ppm)
U.S. Patent # 7,277,177

CRDS Solutions for Fuel Cell Hydrogen Analysis

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HALO 3 NH_3
HALO 3 CH_2O
Trace Level Analyzers for Ammonia and Formaldehyde

Performance in H_2	
Operating range	See table below
Detection limit (MDL)*	See table below
(95% confidence limit)	
SAE J2719 Limit	See table below
Precision (1σ, greater of)	± 1% or 1/2 of MDL
Accuracy (greater of)	± 4% or MDL
Speed of response	< 3 minutes to 90%
Environmental conditions	10°C to 40°C
	30% to 80% RH (non-condensing)
Storage temperature	-10°C to 50°C

Gas Handling System and Conditions	
Wetted materials	316L stainless steel
	10 Ra surface finish
Gas connections	1/4" male VCR
Leak tested to	1 x 10^{-9} mbar l / sec
Inlet pressure	10 – 125 psig (1.7 – 9.6 bara)
Flow rate	1 slpm
Gas temperature	Up to 60°C

Dimensions	H x W x D [in (mm)]
Standard sensor	8.73 x 8.57 x 23.6 (222 x 218 x 599)
Sensor rack	8.73 x 19.0 x 23.6 (222 x 483 x 599)
(fits up to two sensors)	
Weight	
Standard sensor	33 lbs (15 kg)

Electrical	
Alarm indicators	2 user programmable
	1 system fault
	Form C relays
Power requirements	90 – 240 VAC, 50/60 Hz
Power consumption	40 Watts max.
Signal output	Isolated 4–20 mA per sensor
User interfaces	5.7" LCD touchscreen
	10/100 Base-T Ethernet
	802.11g Wireless (optional)
	RS-232

Performance in H_2:	Part Number	Range	MDL*	SAE/ISO Limit
HALO 3 NH_3	F7617	0 – 6 ppm	1.0 ppb	100 ppb
HALO 3 CH_2O	F7618	0 – 40 ppm	2.5 ppb	10 ppb

*Method detection limit (MDL) is determined using U.S. EPA 40 CFR Part 136 Appendix B (95% Confidence Limit)

U.S. Patent # 7,277,177

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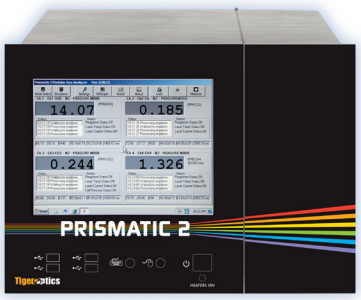
Prismatic™ 2

Multi-Species Gas Analyzer for NH_3, H_2O, CO, CO_2 and CH_4



Performance in H_2	
Operating range	See table below
Detection limit (MDL)*	See table below
(95% confidence limit)	
SAE J2719 Limit	See table below
Precision (1σ, greater of)	± 0.5% or 1/2 of MDL
Accuracy (greater of)	± 4% or MDL
Speed of response	< 5 minutes to 95%
	(in 4-channel operation)
Environmental conditions	10°C to 40°C
	30% to 80% RH (non-condensing)
Storage temperature	-10°C to 50°C
Gas Handling System and Conditions	
Wetted materials	316L stainless steel
	10 Ra surface finish
Gas connections	1/4" male VCR
Leak tested to	1 x 10^{-9} mbar l / sec
Inlet pressure	20 – 125 psig (2.4 – 9.6 bara)
Flow rate	< 1 slpm
Gas temperature	Up to 60°C

Dimensions	H x W x D [in (mm)]
Electronics unit and sensor	12.25 x 17.50 x 29.65
	(311 x 445 x 753)
Weight	
Standard sensor	70.5 lbs (32.0 kg)
Electrical	
Alarm indicators	User programmable setpoints
	(1 per channel), Form C relays
Power requirements	90 – 240 VAC, 50/60 Hz
Power consumption	400 Watts max.
Signal output	0–5 VDC analog
	Isolated 0–20 mA or 4–20 mA
User interfaces	10.4" LCD touchscreen
	PS/2 mouse and keyboard
	10/100 Base-T Ethernet
	4 USB ports, RS-232
Part Number	F8003

The Prismatic™ 2 can be configured to detect a maximum of four different molecules from below list.

Performance in H_2:	Range	MDL*	SAE/ISO Limit
Ammonia (NH_3)	0 – 6 ppm	1 ppb	100 ppb
Moisture (H_2O)	0 – 50 ppm	4 ppb	5000 ppb
Carbon Monoxide (CO)	0 – 1000 ppm	100 ppb	200 ppb
Carbon Dioxide (CO_2)	0 – 3000 ppm	200 ppb	2000 ppb
Methane (CH_4)	0 – 10 ppm	1 ppb	100 ppb†

*Method detection limit (MDL) is determined using U.S. EPA 40 CFR Part 136 Appendix B (95% Confidence Limit)
†Concentration limit when using CH_4 measurement instead of total hydrocarbon (THC) analysis (total THC limit is 2 ppm)
U.S. Patent # 7,277,177

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HALO OK
Trace Level Oxygen Analyzer

Performance in H_2	
Operating range	0 – 40 ppm
Detection limit (MDL)*	2.5 ppb
(95% confidence limit)	
SAE/ISO Limit	5000 ppb
Precision (1σ, greater of)	± 0.75% or 1/2 of MDL
Accuracy (greater of)	± 4% or MDL
Speed of response	< 3 minutes to 95%
Environmental conditions	10°C to 40°C
	30% to 80% RH (non-condensing)
Storage temperature	-10°C to 50°C

Gas Handling System and Conditions	
Wetted materials	316L stainless steel
	10 Ra surface finish
Leak tested to	1 x 10^{-9} mbar l / sec
Gas connections	1/4" male VCR
Sample inlet pressure	10 – 125 psig (1.7 – 9.6 bara)
Sample flow rate	0.5 to 1.8 slpm (gas dependent)
Gas temperature	Up to 60°C

Dimensions	H x W x D [in (mm)]
Standard sensor	8.73 x 19.0 x 23.6 (222 x 483 x 599)
Weight	
Standard sensor	45 lbs (20.4 kg)
Electrical	
Alarm indicators	2 user programmable
	1 system fault
	Form C relays
Power requirements	90 – 240 VAC, 50/60 Hz
Power consumption	200 Watts max.
Signal output	Isolated 4–20 mA
User interfaces	5.7" LCD touchscreen
	10/100 Base-T Ethernet
	802.11g Wireless (optional)
	RS-232
Part Number	F7502-H

*Method detection limit (MDL) is determined using U.S. EPA 40 CFR Part 136 Appendix B (95% Confidence Limit)

U.S. Patent # 7,277,177 • U.S. Patent # 7,255,836

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Advanced Spectroscopic Solutions for Fuel Cell Hydrogen Analysis

Spark

HALO 3

Prismatic™ 2

HALO OK

Annual Remote Certification

- Low-cost and easy remote certification process, with no need to return the analyzer to the factory (it remains in situ)
- Annual re-certification by Tiger Optics ensures that your analyzer continues to meet its original specifications
- Up-to-date Verification Certificate to comply with your QA/QC standards


Tiger Optics LLC

Verification Certificate

Customer: Name
Item: HALO+
Serial Number: 1234-5-6
Date Tested: August 13th, 2014

Tiger Optics, LLC has analyzed the instrument

References

ASTM Standard D7941 / D7941M - 14, "Standard Test Method for Hydrogen Purity Analysis Using a Continuous Wave Cavity Ring-Down Spectroscopy Analyzer" – available from ASTM International, http://www.astm.org/Standards/D7941.htm

SAE J2719, "Hydrogen Fuel Quality for Fuel Cell Vehicles" – available from the Society of Automotive Engineers, http://standards.sae.org/j2719_201109

ISO 14687-2:2012(en), "Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles" – available from the International Organization for Standardization, http://www.iso.org/obp/ui/#iso:std:iso:14687:-2:ed-1:v1:en

EPA 40 CFR Part 136 Appendix B – available from the U.S. Government Publishing Office, Electronic Code of Federal Regulations, http://www.ecfr.gov

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