LUMASENSE® TECHNOLOGIES

AWAKENING YOUR 6th SENSE

GAS SOLUTIONS OVERVIEW

GIVING OUR CUSTOMERS A COMPETITIVE EDGE BY AWAKENING THEIR 6th SENSE

Providing insight and information to help our customers reduce waste and inefficiency in their most resource-intensive processes

LumaSense Technologies, Inc. was founded in 2005 as the world's first company to focus exclusively on reducing preventable waste and inefficiency across our planet's most resource-intensive global industries. umaSense delivers advanced sensing technology to detect, reduce, and prevent waste and inefficiency in resource-intensive industries including Global Energy, Industrial Materials, and Advanced Technologies.

LumaSense enables customers worldwide to achieve predictable and sustainable improvements in process efficiency and waste reduction. These customers have processes that include generating and transmitting electricity; oil and gas refining; processing industrial materials; and manufacturing advanced technologies such as semiconductor, wafers, and LEDs. LumaSense gives our customers a competitive edge by awakening their 6th sense.

What is the 6th sense?

The 6th sense is the power of perception beyond the five senses. Some refer to it as intuition, others say it is the ability to understand the subtle cause and effect relationship behind many events.

LumaSense Technologies provides the sensors and solutions that awaken this 6th sense in customers to allow them to efficiently optimize their processes.

LUMASENSE SOLUTIONS
FOR GAS SENSING

LumaSense Technologies, Inc., delivers innovative temperature and gas sensing instruments for the Global Energy, Industrial Materials, and Advanced Technologies markets.

With a 50-year history of creating efficiencies through light-based measurement, LumaSense delivers advanced sensing technology to detect, reduce, and prevent waste and inefficiency in resource-intensive industries including Global Energy, Industrial Materials, and Advanced Technologies. Our unrivalled passion for excellence is why we have become the one of the world's most trusted sensing solution providers.

Our gas portfolio not only helps our customers achieve process efficiency and waste reduction, but monitors the world's most harmful and dangerous gases. Because our gas sensing solutions offer superior sensitivity over other gas detection techniques, our gas modules and instruments are particularly beneficial when the environment and human safety are involved.

As a leader in trace and multi-gas monitoring, LumaSense delivers a complete range of NDIR and PAS gas solutions for all kinds of environments and applications in the Global Energy, Industrial Materials, and Advanced Technologies markets.

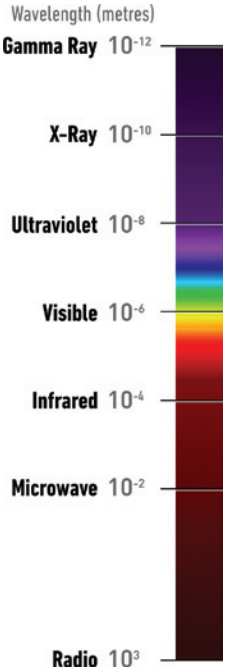
INNOVATIONS IN GAS SENSING

While there are numerous ways to detect and analyze gases, at LumaSense we utilize two different types of infrared (IR) technologies to deliver cost-effect solutions with high sensitivity, accuracy, and reliability.

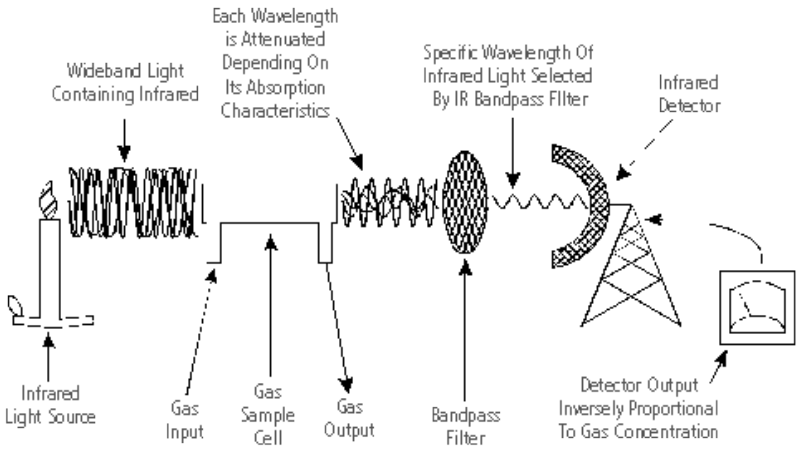
NON-DISPERSIVE INFRARED GAS SPECTROSCOPY

Non-Dispersive Infrared (NDIR) quantifies known gases. While the technology has long existed, LumaSense Technologies' ANDROS® brand pioneered NDIR gas analysis for automotive emissions and patient monitoring. NDIR is the heart of our suite of SmartDGA products designed for the Energy industry for Dissolved Gas Analysis (DGA) of transformers and load tap changers (LTCs). In addition, we developed a unique single path approach. With ANDROS® NDIR modules, the cost of gas measurement is greatly reduced because our modules can measure multiple gases and field calibration is not needed.

The main components of NDIR gas sensors are: an IR source (lamp), a gas sample chamber or light tube, an optical bandpass filter and the infrared detector. The gas is pumped or diffuses into the sample chamber and the gas concentration is measured electro-optically by its absorption of a specific wavelength in the IR spectrum. The IR light is directed through the sample chamber towards the detector. The detector has an optical filter in front of it that eliminates all light except the wavelength that the selected gas molecules can absorb (see diagram below).



As many gases absorb well in the IR area, it is often necessary to compensate for interfering components. For instance, CO_2 and H_2O often display cross sensitivity in the infrared spectrum. The IR signal from the source is modulated so that thermal background signals can be offset from the desired signal.



Single Beam Gas Analyzer Diagram

Benefits of NDIR and PAS Technologies

Accurately Measure

- Concentrations from ppb, ppm to percent range
- Compensate for temperature, pressure and humidity interference

Simplify Gas Detection

- Monitor up to 6 gases (SmartDGA) simultaneously with one product
- Fast response time
- Easy set-up and remote control operations

Protect Valuable Resources

- Detect harmful gases
- Reduce risk to human health and safety
- Preserve natural resources

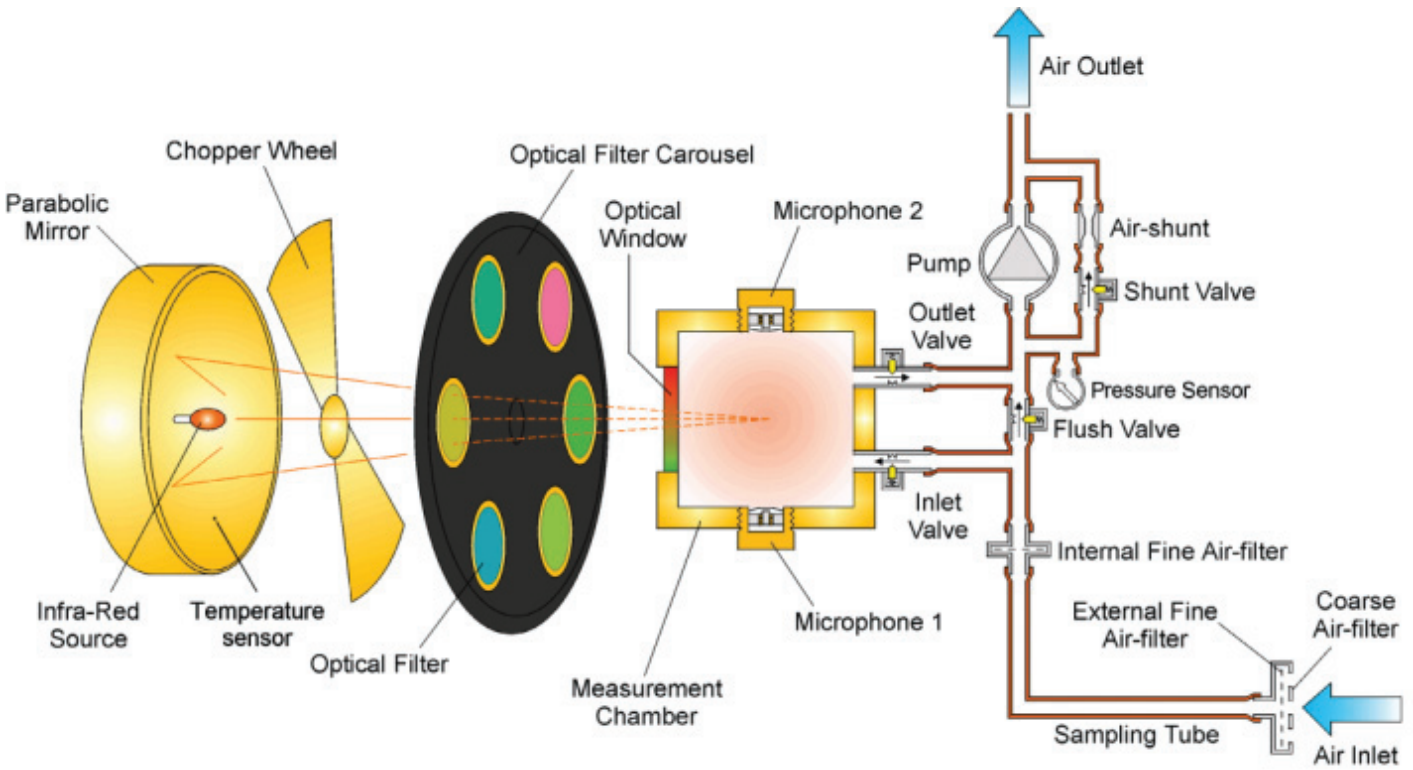
PHOTOACOUSTIC SPECTROSCOPY

Photoacoustic Spectroscopy (PAS) gas instruments were perfected by INNOVA™. With PAS, the absorption (proportional to the concentration) is measured directly and not relative to a background. This means that PAS is highly accurate and stable. Furthermore, all gases and vapours in small volumes can be monitored sequentially in a single measurement chamber as it is possible to detect up to five substance and humidity to be monitored individually.

In a PAS instrument, the gas to be measured is irradiated by modulated infrared light of a pre-selected wavelength. The gas molecules absorb some of the light energy and convert it into an acoustic signal which is detected by microphones.

The IR-source is a spherical, heated black body. An ellipsoidal mirror focuses the light into a closed PAS cell through a window after it has passed the light chopper and the optical filter. The chopper rotates and effectively switches the light on and off. The optical filter is a narrow-band state of the art IR interference filter. If the frequency of the light coincides with an absorption band of the gas in the cell, the gas molecule will absorb part of the light. The higher the concentration of gas in the cell, the more light will be absorbed. As the gas absorbs energy, it is heated and therefore expands and causes a pressure rise. As the light is chopped, the pressure will alternately increase and decrease thus generating an acoustic signal. The acoustic signal is detected by two microphones. The electrical output signals from the two microphones are added in an amplifier, before they are processed.

The two technologies are packaged and delivered as either ANDROS® brand gas modules, or as INNOVA™ or LumaSense brand gas instruments that are available directly to end users.



SF_6 MEASUREMENT SOLUTIONS

Over the last few decades, energy equipment manufacturers have been using Sulfur Hexafluoride (SF_6) instead of oil in high voltage switch gear units. In fact, the power industry uses roughly 80% of the SF_6 produced globally. However, SF_6 is one of the most potent greenhouse gases; consequently its use is highly regulated. Power equipment manufacturers must ensure their equipment will not leak SF_6 as part of their final quality assurance testing. Plus, the utilities that purchase the equipment must monitor the leakage from the equipment to ensure personnel safety, ensure equipment performance and avoid heavy fines due to environmental discharges. Utilities monitor closely in enclosed locations (like GIS installations) or open air switchyards.

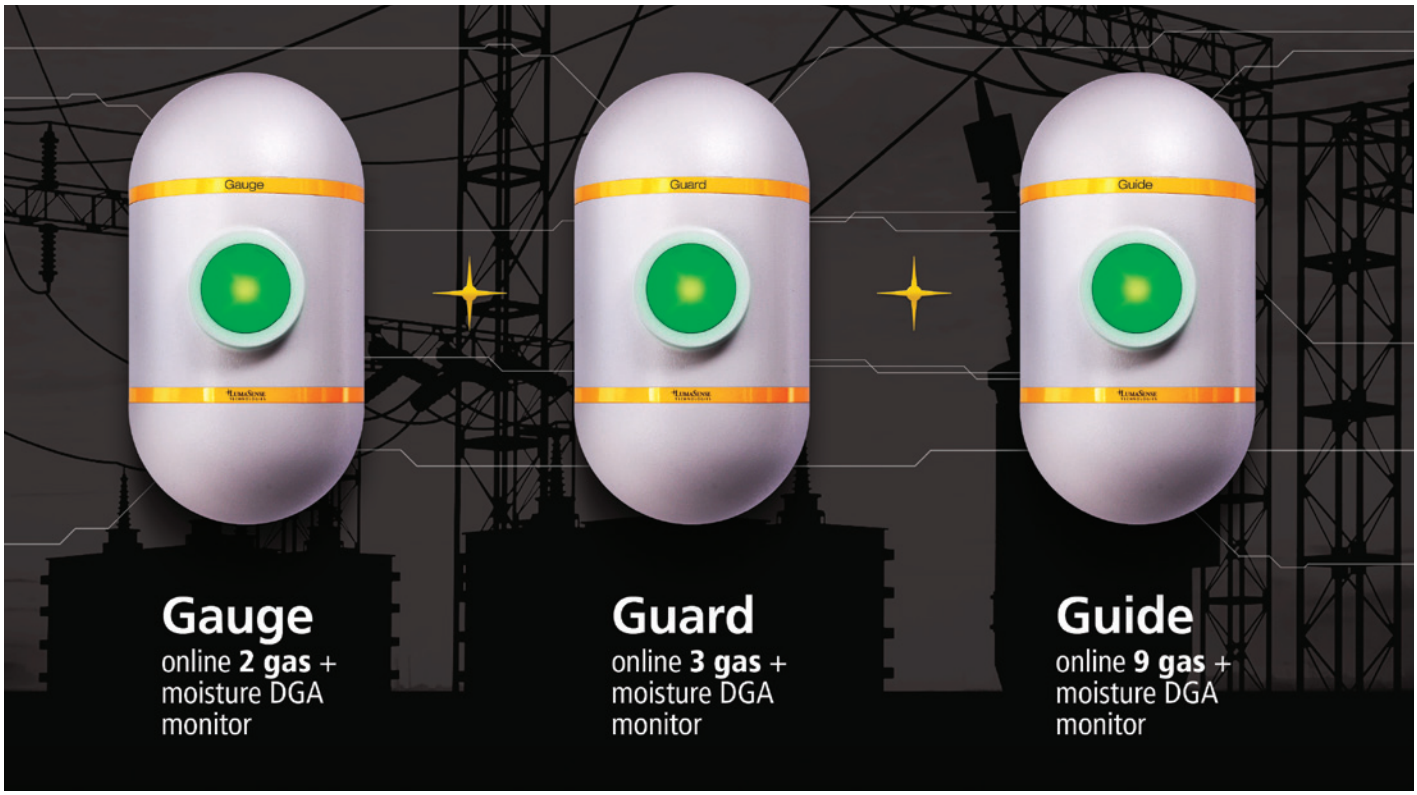
LumaSense offers both SF_6 leak detection and closed area monitoring solutions so both manufacturers and utilities can comply with those regulations.

SF_6 Leak Detector 3434i

- Highly-sensitive to measure smallest leaks and leak rate
- Easy to operate
- Extremely stable and reliable, with low maintenance costs

SF_6 Area Monitoring Solutions with Multipoint Sampler INNOVA 1309

- Low detection limits allow utilities to quickly detect leaks to maintain safety of enclosed areas with SF_6 equipment
- Monitors can operate unattended, over wide areas and for long periods of time
- Easy to use LumaSoft Gas 7860 Software User interface to report events and alarms in up to 24 locations



DISSOLVED GAS ANALYSIS (DGA) FOR TRANSFORMER MONITORING

In 2012, LumaSense Technologies released SmartDGA – a new category of DGA monitors designed for easy installation, high performance, large scale deployments and to help utilities achieve fleet-wide usage of transformer and load tap changer (LTC) DGA monitoring. Using field proven Non-Dispersive Infrared (NDIR) sensing platform, innovative gas separation technology, and innovative design, SmartDGA is designed to be Easy... easy to buy, install, and maintain.

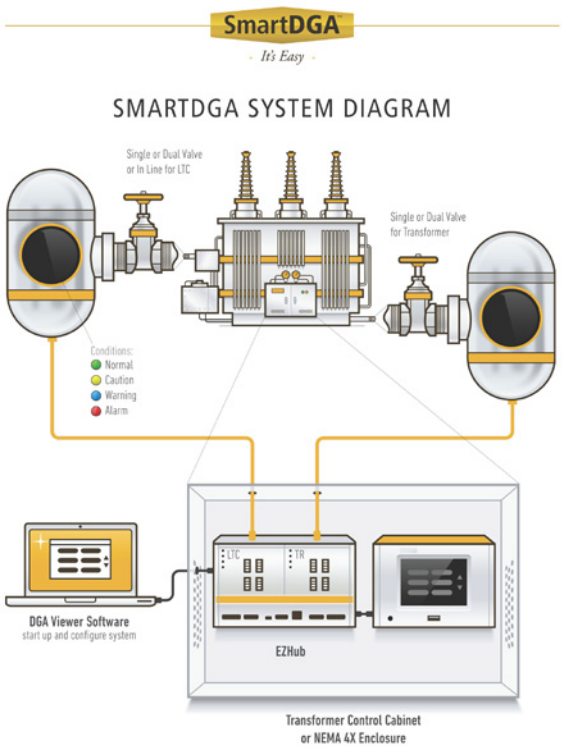
SmartDGA addresses three major challenges:

- **Cost of ownership:** most DGA monitors are too expensive to support wide-scale deployment, thus limiting the ability to realize a Smart Grid and true condition-based maintenance. SmartDGA brings a total cost of ownership up to 80% less than what is seen in the market today.
- **Flexibility:** online DGA systems lack flexibility and the ability to accurately identify and mitigate faults. SmartDGA has flexible mounting and configuration, which can easily be expanded upon.
- **Ease-of-Use:** most monitoring technologies are cumbersome to install, maintain and service, leading to a poor overall user experience. SmartDGA is simple to install, simple to use and simple to upkeep.

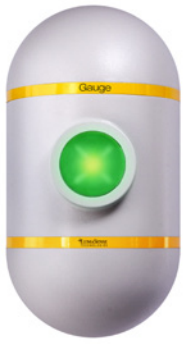
THE SMARTDGA SYSTEM

LumaSense has developed a cost-effective online monitoring solution based on proven, state-of-the-art non-dispersive infrared (NDIR) technology. This new suite of products is designed to allow customers to continuously monitor and control the condition of LTCs and transformers.

- The **SmartDGA Gauge™** is the industry's first dedicated online load tap changer (LTC) condition monitor. With the ability to monitor ethylene (C_2H_4), acetylene (C_2H_2) and moisture without maintenance and routine calibration, it offers the best value to assess LTC health.
- The **SmartDGA Guard™** provides reliable early warning diagnostics to prevent transformer failures. It measures and reports Hydrogen (H_2), Carbon monoxide (CO), acetylene (C_2H_2) and moisture for incipient fault detection without routine maintenance, calibration or need for carrier gas.
- The **SmartDGA Guide™** provides comprehensive online Dissolved Gas Analysis (DGA) monitoring and diagnostics to prevent transformer failures. It measures and reports all DGA gases at half the cost of other 9 gas DGA monitors. Furthermore, the Guide vastly reduces total cost of ownership due to its differentiated design and installation scheme.



- The **SmartDGA EZHub™** is designed for easy connectivity. It provides power and communications (RS485 and ethernet) for the SmartDGA system. It has on-board memory storage and allows for easy upload and download of data and updates via a USB connection.
- The **LUMASMART *i*Core™** provides Smart grid ready advanced communications like IEC 61850, DNP3, MODBUS. It also provides high powered computerized display for viewing, trending, and diagnostics as well as long term memory storage.



INDUSTRIAL COMBUSTION MONITORING

Industrial pollution can be mitigated monitoring waste gases such as carbon dioxide (CO_2), Hydrogen sulfide (H_2S) and oxides of nitrogen (NO_x).

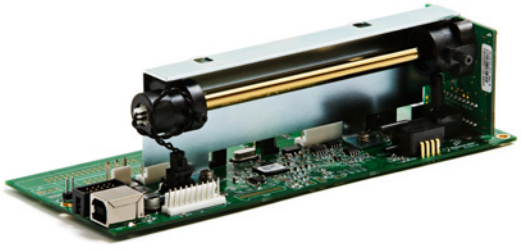
Andros 6500 Gas Module

- Measures CO, CO_2, and Hexane or Propane up to high concentrations with NDIR
- Measures O_2, NO and NO_2 with chemical sensors

Multi Gas Monitor INNOVA 1316-1

- Measures CO, CO_2 and hydrocarbons (either hexane or propane)
- Measure O_2 and NO when combined with optional chemical sensors

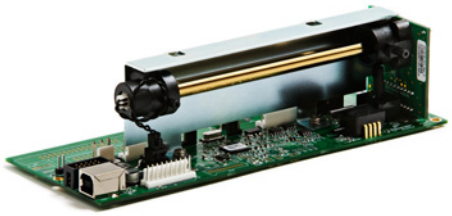
The 1316 is a reliable and field-proven product that uses NDIR technology, which is particularly beneficial in harsh industrial environments because our instruments have no moving parts in the optical path, seldom require calibrations and automatically compensate for drift while measurements are performed. NDIR gas instruments like the 1316 have been used for measuring fumes from industrial printing processes, monitoring filter break through and scrubber efficiency and analysing exhaust from smoke stacks.



REFRIGERANT GAS LEAK DETECTION

Refrigerant gas leak detection is becoming a high priority due to the risk to the environment, the increasing price of refrigerant gas and the high price for repair of major leaks. The need for accurate refrigerant gas detection is also driven by tightening regulations such as the European F-Gas Directive and EN378 legislation.

- The Andros 6552 NDIR gas module with two gas channels can be applied to any type or combination of refrigeration systems that may employ CFC, HFC, HCFCs and CO_2.
- Low power consumption and low maintenance designed to meet or exceed EN 14624, performance of mobile leak detectors and of room controllers of halogenated refrigerants.



ENVIRONMENTAL EMISSION MONITORING

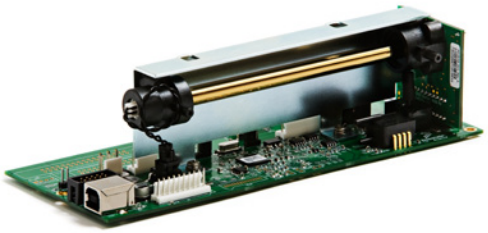
There is an expanding list of environmental and emission applications where gas sensing solutions are needed. Our INNOVA gas instruments have measured NH_3 in swine and poultry stables, CH_4 in cattle and poultry stables, N_2O from stables and fertilizer, CH_4 from decomposing biomass and organo-phosphorous compounds in greenhouses and rice cropping.

The INNOVA 1412i is a versatile gas monitor broadly used in research and development projects like:

- Agriculture emission reduction from soils, manure, and livestock housing
- Greenhouse gas emissions monitoring
- Remedial soil contamination system efficiency

ANDROS 6511: gas module is used for greenhouse gas and landfill methane monitoring

- Continuous, real-time measurement of multiple components including methane and carbon dioxide.
- Special version extremely stable (non zero request) compatible with Gas industry explosive environment.



Our Commitment to Help Control Harmful Environmental Pollutants

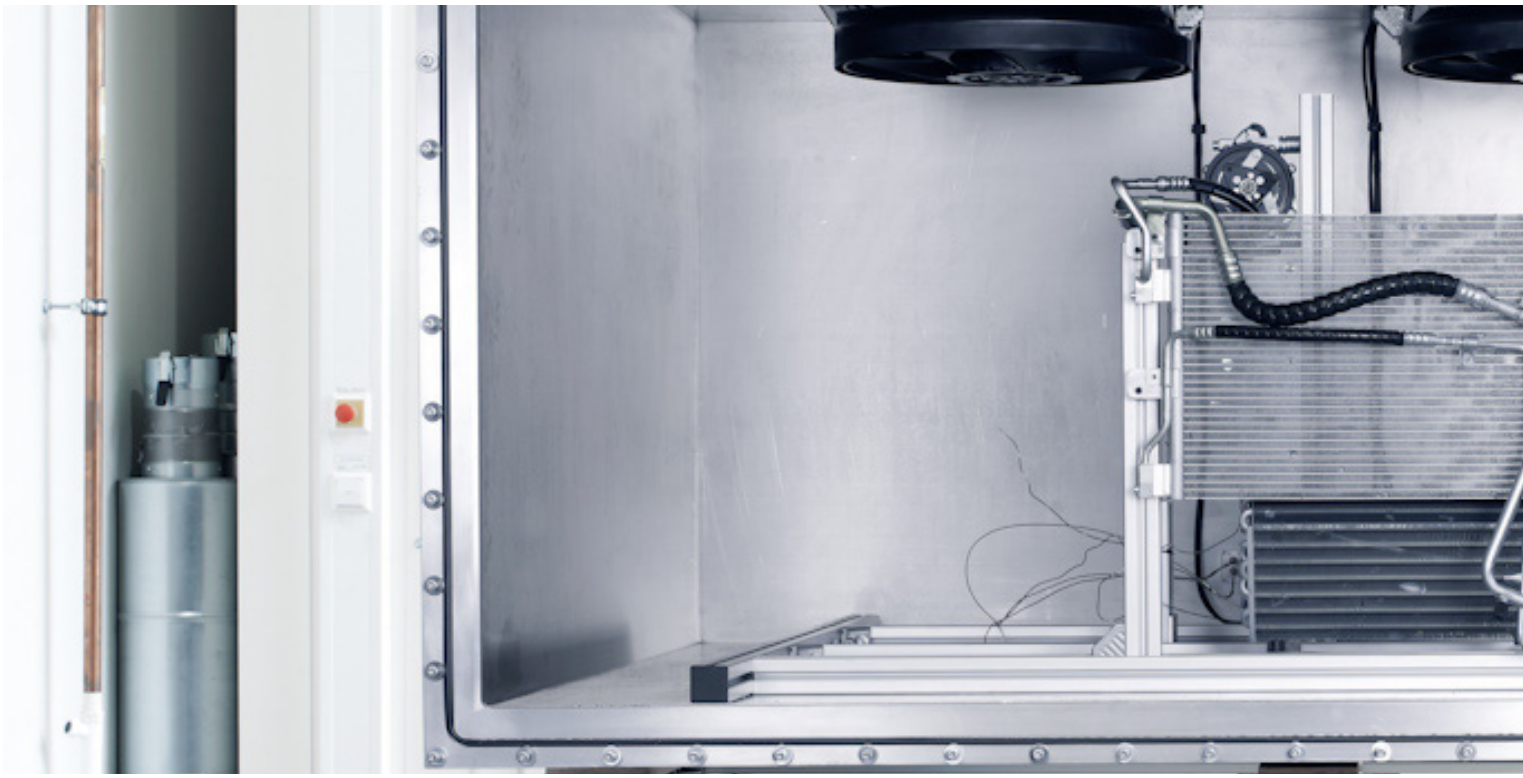
Guided by our mission and vision to detect, reduce, and prevent waste and inefficiency for resource-intensive customers, we are serious about developing products that help in the global effort to control and reduce the emission of greenhouse gases and harmful environmental pollutants.

LumaSense delivers advanced sensing solutions that measure the most important greenhouse gases including: ammonia, carbon dioxide, methane, CFCs based refrigerants and nitrous oxide. PAS makes it possible to measure greenhouse gases quickly and accurately with a single instrument. Using the Windows compatible software included with our monitors, it is possible to zoom in on a single sample, giving a true time relationship for up to five gases plus water vapor.

FERMENTATION PROCESSES

Traditional means of gas measurement that require constant conditions are not well suited for fermentation metabolism. Exhaust gas measurement based on the ratio of CO_2 production and O_2 consumption (i.e. the Respiratory Quotient) is ideal. Exhaust gas analysis of fermentation process using NDIR technology is both accurate and cost-effective.

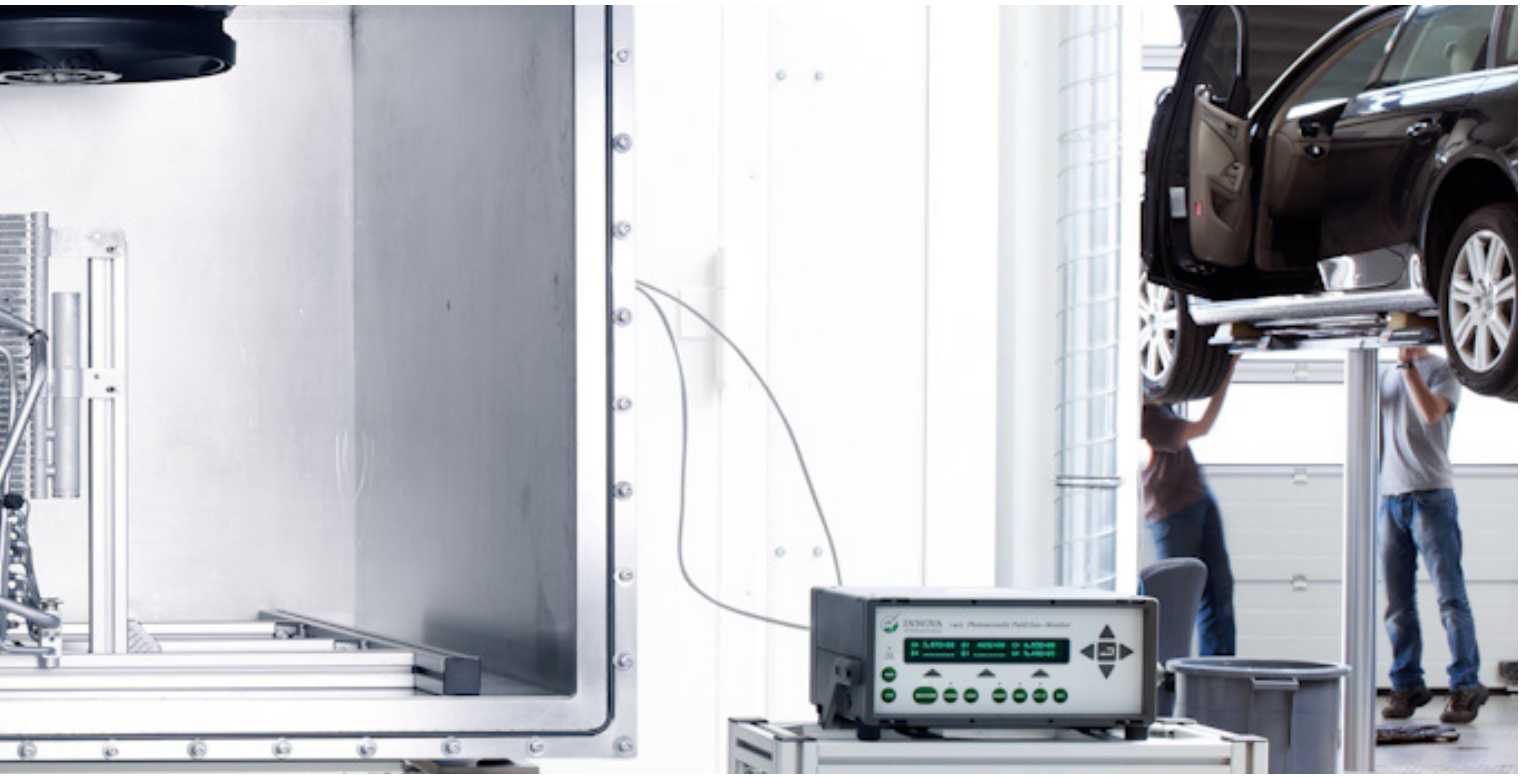
- The INNOVA 1316-3 is triple-gas monitor that can measure CO_2, O_2 and Ethanol simultaneously from a single sampling point.
- The 1316-3 has fast warm-up and response times. It is exceptionally easy to use and is scalable with the 7950 multi-point software.



AUTOMOTIVE EMISSIONS MONITORING

LumaSense is the pioneer manufacturer of NDIR based gas modules for the automotive testing industry with an installed base exceeding 450,000 units. For vehicle diagnostic, inspection and maintenance programs our ANDROS 6500 series gas module offers:

- Unparalleled accuracy and performance through simplicity of design and implementation,
- Easy integration and upgrade with flexible configuration thanks to the Andros operating system and development software,
- Low power consumption, low maintenance and cost of ownership.



Test setup at IPETRONIK (in Germany) with the INNOVA 1412i for monitoring emission values of R134a or HFO-1234yf.

Modern automobiles are manufactured with sophisticated sensors, computer controls, and on board diagnostics (OBD). Even when all systems are operating correctly, engine emissions can be higher than the original regulatory standards. Many failures cannot be determined by OBD diagnostics alone, so the only way to know how well the engine is performing is to measure the tail pipe emissions using an NDIR based diagnostic instrument.

- The ANDROS 6500 Auto Emissions gas module is manufactured and tested to meet the limits defined in any of the worldwide requirements to ensure the OEM is receiving the highest measurement performance capability.

- The ANDROS 6500 is designed to meet and exceed ISO 3930/OIML R99, Class 0 and BAR 97 specifications.

For vehicle testing and engine design validation, several gases (NH_3, EtOH, and N_2O) need to be measured. LumaSense's INNOVA 3433 Multi Gas monitor is used to measure evaporation emissions (SHED) and vehicle exhaust gas (Constant Volume Samples CVS) approved by EPA and CARB. The INNOVA 1412i can be used for measurements of Mobile Air Conditioner emissions R134a and HFO-1234yf.

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