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The Safety Company

Improving Line-of-Sight Gas Monitoring Using Enhanced Laser Diode Spectroscopy (ELDS)

White Paper

WE KNOW WHAT'S AT STAKE.

Background

Open Path Gas Detectors (OPGD) have been used since the late 1980s and are commonly used to detect hydrocarbon gas leaks at oil and gas production facilities, refineries, petrochemical plants, gas transmission stations, fertilizer plants, and many other industrial facilities. They frequently are used in conjunction with point gas detectors to provide comprehensive facility coverage, especially for high-risk applications where the early detection of the gas leak is important.

This white paper outlines the advantages of laser-based OPGD over conventional Non-Dispersive Infrared (NDIR) OPGD. OPGD systems comprise of two units: a Transmitter or Source, which emits an Infrared (IR) beam; and a Receiver, that detects (receives) the beam. The area between the Transmitter and Receiver is known as the open path or line of sight. Once the gas cloud migrates to the IR beam, it is detected, and the alarm is raised.

NDIR OPGD respond to the presence of many different hydrocarbon gases. Each system is calibrated for life at the time of manufacture to read correctly for a specific hydrocarbon; however, an NDIR OPGD will still be able to detect other hydrocarbon gases. These systems are not able to identify which hydrocarbon gas is being detected.

The OPGD is an excellent solution for detecting gas clouds as they migrate from the source of the gas leak across a site, and which may go undetected by a point gas detector. They are also an exceptional solution for perimeter fence line monitoring, where the boundary fence of the facility is so long that it's impractical to use point gas detectors.

The gas measurement is based on the amount of the IR radiation that is absorbed by the gas within the beam. This is then expressed as LEL.m (Lower Explosive Limit—meters). As shown below in *Figure 1*, a small, concentrated gas cloud and a large, less concentrated gas cloud can yield the same measurement value. This is because both of these gas clouds would absorb the same amount of infrared radiation in the beam.

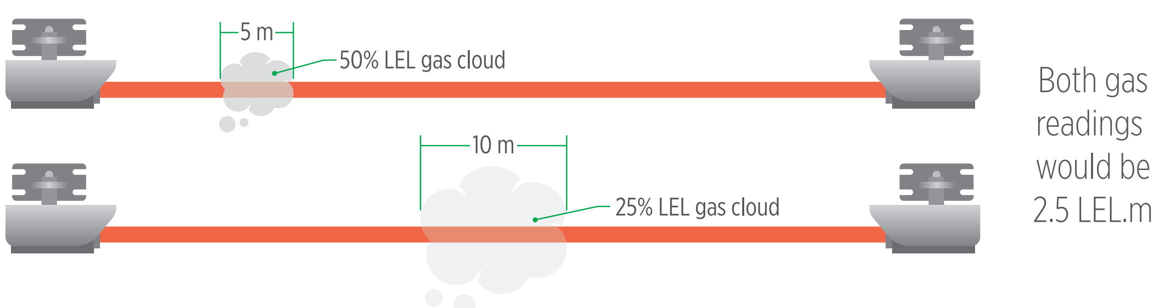


Figure 1. Gas cloud concentrations and OPGD gas readings.

Since the introduction of NDIR-based OPGD for hydrocarbon gases, end users have requested additional capabilities for OPGD, which include:

Increased sensitivity

(The ability to detect lower concentrations of the escaping gas)

Target gas specific

(Methane-specific with no cross sensitivity to any other hydrocarbon gases)

Increased uptime availability in severe weather conditions

(Suitable for climates subject to heavy rain and fog)

The ability to detect toxic gas releases

(Hydrogen Sulfide, Ammonia, Carbon Dioxide, Hydrogen Fluoride, Hydrogen Chloride)

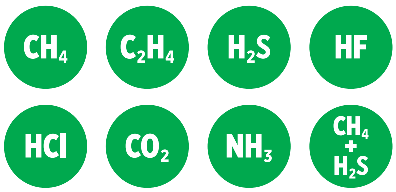
Auto self-testing

(To reduce routine manual testing and cost)

These additional end user requirements are beyond the capabilities of traditional NDIR OPGD systems which have led to the design and development of laser-based Open Path Gas Detectors.

MSA/Senscient launched its range of laser-based OPGD in 2009 using a technique called Enhanced Laser Diode Spectroscopy (ELDS™).

These Devices...



Are target gas specific and available for Methane, Ethylene, Hydrogen Sulfide, Hydrogen Fluoride, Hydrogen Chloride, Carbon Dioxide, Ammonia, or Sour Gas *(Hydrogen Sulfide entrained within Methane)*

Offer three orders of magnitude in increased sensitivity for hydrocarbons, greatly increasing the probability of detecting a flammable gas leak before it reaches catastrophic proportions

Include the unique self-test facility called SimuGas™ that enables automatic or on demand functional testing of open path gas detectors

ELDS utilizes highly reliable, solid-state laser diode sources similar to those used in demanding telecommunications applications. Innovative signal processing methods significantly increase sensitivity, enabling reliable detection to much lower LEL.meter values of combustible gases compared to NDIR OPGD, and low ppm.meter levels of toxic gases. ELDS addresses problems experienced by traditional laser diode systems including laser Relative Intensity Noise (RIN), absorption by atmospheric gases, and coherence/fringe effects, which can result in false positives and unwanted plant shutdowns. ELDS uses a combination of techniques which significantly enhance the ability of an OPGD to detect small fractional absorbances with an excellent low false alarm rate.

Principle of Operation

Using a separate transmitter/receiver configuration, ELDS systems detect and measure gas concentrations at specific target gas absorption wavelengths over distances of up to 200 meters (gas dependant).

Transmitter

The unique design of the Senscient ELDS transmitter assembly comprises of a hazardous area certified enclosure that houses the laser, collimating optics, a gas reference cell filled with a sample of the target gas, and drive electronics *(Figure 2)*.

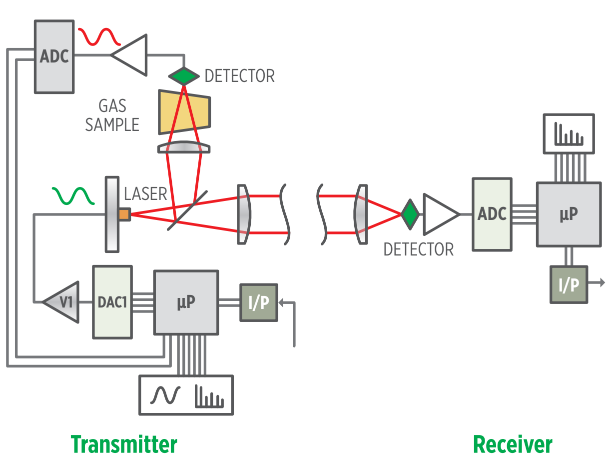


Figure 2. ELDS system schematic

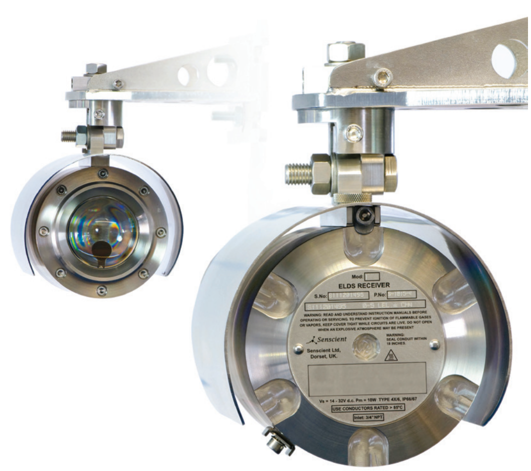


Figure 3. ELDS Transmitter & Receiver

The laser diode is driven by a current and generates infrared radiation at a known absorption wavelength of the target gas. The laser is then scanned across this absorption wavelength for a designated time interval. Every Senscient ELDS transmitter contains a hermetically sealed gas reference cell filled with a sample of the detector's target gas(es), which is monitored by a dedicated photodiode to ensure the laser remains locked on the absorption wavelength. This ensures the system will respond to the target gas and reduces the possibility of an unrevealed failure often associated with devices that do not use a gas reference cell filled with the target gas.

Receiver

The receiver analyzes the incoming signal using the well proven technique known as Fourier transform. Fourier transform is commonly used within laser-based process gas analyzers and converts the incoming signal from the time domain into a frequency domain.

When viewed in the frequency domain, the incoming signal is presented as a single harmonic frequency (f) when no gas is present *(Figure 4)* or a number of harmonic frequencies f (f^2, f^3, f^4, f^5) when the target gas is present in the path *(Figure 5)*.

The inter-relationship/pattern and phases of these harmonics (f^2, f^3, f^4, f^5) for a specific gas are unique to that gas and represents its harmonic fingerprint. A harmonic fingerprint that does not match that of the target gas may have resulted from an interferent gas or environmental condition and is rejected.

Harmonic fingerprint analysis, using multiple harmonics (f^2, f^3, f^4, f^5) ensures the device only responds to the target gas, eliminating false alarms associated to devices that only look for the presence of one harmonic (f^2).

The amplitude of the harmonics is proportional to the gas concentration. Gas concentration is then reported via the proportional, analog (mA) output to an associated control system to initiate executive action.

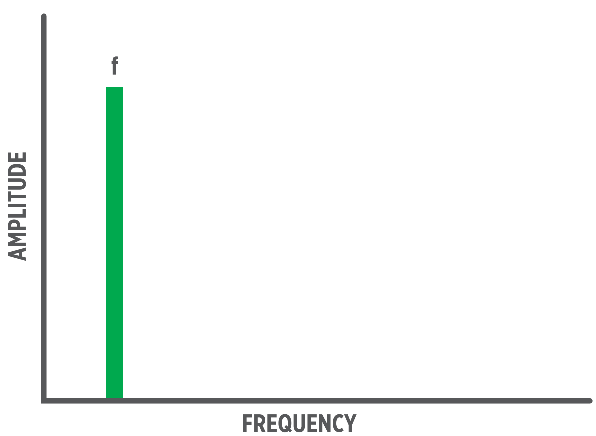


Figure 4. Fourier Transform of Zero Gas Signal

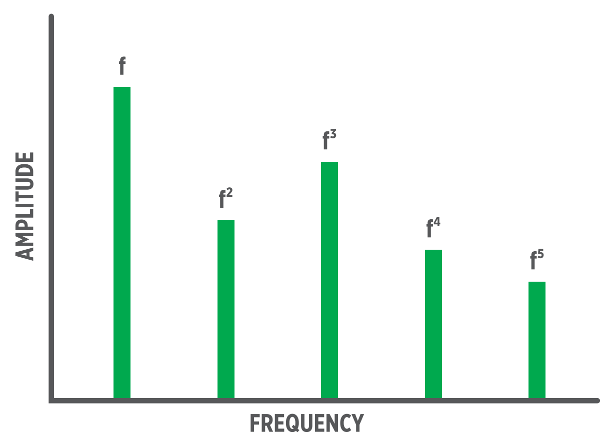


Figure 5. Fourier Transform of Positive Gas Signal

Multiple wavelength detection

Within the operating range of laser diodes, some target gases exhibit limited levels of IR absorption (i.e. Hydrogen Sulfide).

With limited IR absorption and lower signal levels, there is a greater risk of a false alarm from severe environmental conditions and integral system noise. Therefore, additional measures are essential to validate the presence of the target gas.

For these gases, two lasers driven to two known, but different, absorption wavelengths of the target gas, plus advanced signal processing algorithms, provides the highest level of false alarm rejection. This dual laser/wavelength operation, along with processing the data associated to eight harmonics (four from each wavelength) provides dependable operation in the worst of environmental conditions.

Uptime Availability

Traditional NDIR OPGD operates at wavelengths in the region of 2.2 to 2.3 microns or 3.0 to 3.3 microns. While both IR wavelength ranges are suitable for detecting hydrocarbon gases, both ranges are prone to a significant loss of signal at the receiver when the detection path contains steam, rain, or fog.

ELDS systems operate in the region of 1.6 microns where the loss of signal due to steam, rain, or fog is significantly less. It is for this reason that laser-based OPGD is being used as the preferred method of detection in these challenging environments.

However, it should be noted that while laser-based OPGD uptime availability will generally outperform NDIR OPGD, it still has its limits and as with any OPGD design, the path length should always be kept as short as possible.

Proof testing

Traditional NDIR OPGD can be proof tested using a gassing cell that is manually fixed to the receiver. The gassing cell is a tube with optical windows at each end that can be filled with a known concentration of test gas.

An alternative is to use optical filters. These are thin plastic film discs that are inserted at the receiver of various thicknesses. As these devices are not target gas specific, they respond to these plastic (hydrocarbon) filters. The range of thicknesses generate a different up-scale reading.

Laser-based OPGD are target gas specific and therefore will not respond to plastic (hydrocarbon-based) filters. For laser-based systems, it is possible to have a gassing cell arrangement for target gases that are environmentally stable, e.g. Methane, Ethylene, Hydrogen Sulfide, and Carbon Dioxide.

An alternative solution for all detectable target gases within the Senscient ELDS range is the use of the unique SimuGas™ test function.

SimuGas

SimuGas is a simple and reliable gas detector functional test. In a Senscient ELDS system with SimuGas (as shown in *Figure 2)*, the transmitter's microprocessor has direct control of the synthesis of the laser diode drive waveforms and access to the harmonic fingerprints being produced by the absorption of laser diode radiation by the retained sample of target gas.

Upon receiving a command instruction from an operator or control system, the transmitter's microprocessor adds harmonic fingerprint components to the laser diode drive waveforms to simulate the presence of a given quantity of target gas in the monitored space. The optical radiation leaving the transmitter then simulates the presence of target gas in the monitored path. When the receiver processes the signal that it is receiving from the transmitter, it sees the harmonic fingerprint components and calculates and outputs the corresponding quantity of target gas. By simply comparing the gas reading output by the receiver to the quantity of target gas that the transmitter was instructed to simulate, it is possible to verify the correct operation of the gas detector. To avoid unwanted activation of executive actions during a SimuGas test, the analog (mA) output of the receiver is held at the value immediately prior to the SimuGas test for the duration of the test.

SimuGas testing of all ELDS systems is performed automatically every 24 hours and can also be initiated on demand. SimuGas test results are held within an onboard event log and can be retrieved for future use. Subsequent test failures will generate a fault output.

SimuGas testing has the following advantages:

- Functional testing can be performed remotely, eliminating the requirement of equipment (e.g. scaffolding, fall protection) to reach inaccessible areas
- Gas detectors can be functionally tested more frequently, providing greater safety integrity
- There is no need for operators to carry cylinders of hazardous gases around facilities to test gas detectors
- The results of detector functionality testing can be gathered and logged automatically
- The operation and maintenance costs for a gas detection system are greatly reduced

Applications

Similar to traditional NDIR-based OPGD, laser-based OPGDs are used for monitoring:

- Plant Perimeters
- Process Area Boundaries
- Process Pipe Racks
- Process Pump Rows
- Tank Farms
- Air Intakes
- Road/Rail Loading Areas
- Loading Jetties
- And Many More

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Conclusion

Laser-based OPGD is an effective gas detection technology that compliments and/or addresses the limitations of traditional NDIR gas detection technologies providing:

- Combustible or toxic gas detection capability
- Target gas specific detection
- Increased detection sensitivity
- Faster speeds of response
- Reduction of false alarms
- Minimal maintenance costs
- Reduction in the frequency of personnel visiting a designated hazardous area

This table provides an overview of the detectable gases, the possible measurement ranges, path lengths, and the response time of the various models of Senscient ELDS Detectors.

Target Gases	Detection ranges	Path length (meters)*					T_{90}< (sec)
		0.5-5	*5-40*	*5-60*	*40-120*	*120-200*	
CH_4	0-10, 25, 100% LEL (HVAC intake)	■					1
CH_4	0-1000 ppm.m, 0-1, 0-5 LEL.m		■		■	■	3
$CH_4 + H_2S$	0-1 LEL.m + 0-250, 500, 15000 ppm.m			■			5
ETHYLENE	0-10,000 ppm.m, 0-1 LEL.m		■		■	■	3
CO_2	0-300,000 ppm.m		■		■		5
H_2S	0-250, 500, 1000, 1500, 5000, 15000 ppm.m			■			5
HCL	0-50 ppm.m			■			5
HF	0-25, 50, 200, 1000 ppm.m			■	■		5
NH_3	0-200, 1000, 5000, 15,000 ppm.m		■		■		5

** Maximum path length dependent upon selected measuring range, see ELDS gas specific data sheets for details.*

Click here for further information on the Senscient ELDS Open Path Gas Detector:

MSA operates in over 40 countries worldwide. To find an MSA office near you, please visit ***MSAsafety.com/offices***.