Enhanced Laser Diode Spectroscopy Design for High Integrity Gas Detection Applications

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ABSTRACT

Operators of gas detection systems used in safety-critical applications in the hydrocarbon processing, petrochemical and other industries are increasingly looking for rugged fixed, open path (line-of-site) gas detectors featuring high safety integrity with low levels of maintenance and total cost of ownership. Enhanced Laser Diode Spectroscopy™ (ELDS™) is a unique class of laser diode spectroscopy that includes techniques for increasing sensitivity and reliability for gas detection applications. The design of an open path gas detection (OPGD) system with ELDS can meet industry requirements for high safety integrity and low maintenance with two proprietary ELDS techniques: harmonic fingerprints and automatic functional testing of gas detectors. Harmonic Fingerprinting enables new levels of precision and reliability of target gas identification. Simulated gas detection enables simple, remote functional testing without the traditional requirement to apply a test gas to a detector in the field.

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INTRODUCTION

Open Path Gas Detectors (OPGD) using Non-dispersive Infrared (NDIR) detection techniques have been in use since the late 1980's for Oil & Gas, Petrochemical and other safety-critical toxic and combustible gas detection applications. Traditional NDIR open path gas detection systems require costly routine in-field maintenance and the handling of dangerous test gases. Conventional NDIR fixed gas detectors can also become faulty, preventing them from detecting toxic or flammable gases without warning.

To mitigate functional risks, routine functional testing to identify potentially faulty sensors is performed by applying test gas directly to the detectors. However, this introduces problems:

1. Generating, handling, and the application of hazardous gases in the field adds risk.

2. Gaining physical access to detectors can be problematic.

3. Coordination of detector testing with a control system is disruptive and mistake-prone.

4. Costs and logistical efforts are very high, leading to extended test intervals and the potential of detector failure.

Current methodologies for functionally testing traditional fixed detectors is problematic and inadequate.

CONVENTIONAL LASER DIODE SPECTROSCOPY (LDS)

In conventional line-of-site LDS detectors, a sinusoidal current modulation at a frequency f is applied to a laser diode in a transmitter. By ramping its drive current the laser diode operating wavelength is swept over an absorption line of the target gas. When the laser diode operating wavelength coincides with the target gas absorption line, any absorption of optical radiation by the target gas distorts the sinusoidal modulation waveform upon laser diode output. This introduces distortion components at harmonics of the fundamental modulation frequency f (i.e. @ frequencies $2f$, $3f$, $4f$ etc..)

The receiver measures the magnitude of one of the harmonics of the modulation frequency as the transmitted laser diode wavelength is ramped over the target gas absorption line, and estimates the amount of gas present in the measurement path based upon change in magnitude of the chosen harmonic during the ramp cycle. Unfortunately, the formation of coherent interference fringes and absorption by nearby atmospheric gas absorption lines also cause the magnitude of the chosen harmonic to vary during the ramp cycle reducing reliable detection at low gas concentrations. Consequently, conventional LDS systems are not suitable for sensitive gas detection of toxic or combustible gases at levels required for industrial safety applications.

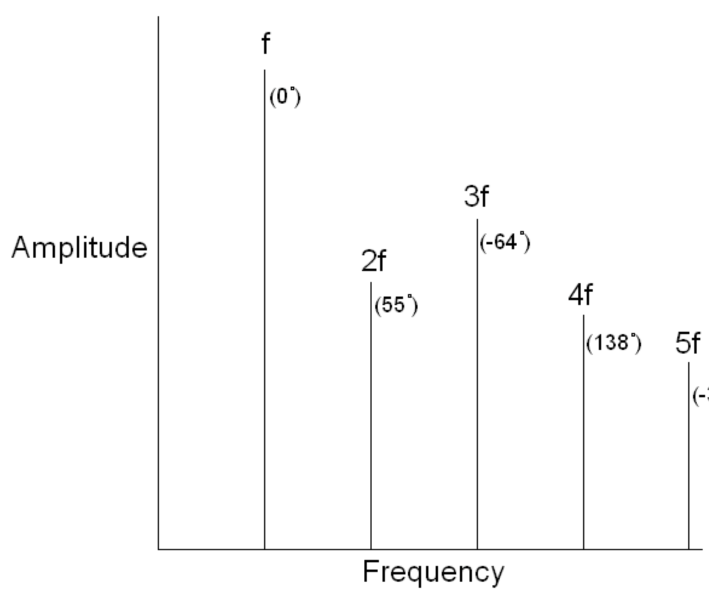
ENHANCED LASER DIODE SPECTROSCOPY (ELDS)

Enhanced Laser Diode Spectroscopy (ELDS) is a new class of laser diode spectroscopy for gas detection that significantly increases the sensitivity and reliability of laser-diode-based gas detection and measurement, even in extreme environments. ELDS uses Harmonic Fingerprinting to achieve the earliest possible detection of gas leaks while reducing the negative repercussions of false alarms.

HARMONIC FINGERPRINTS

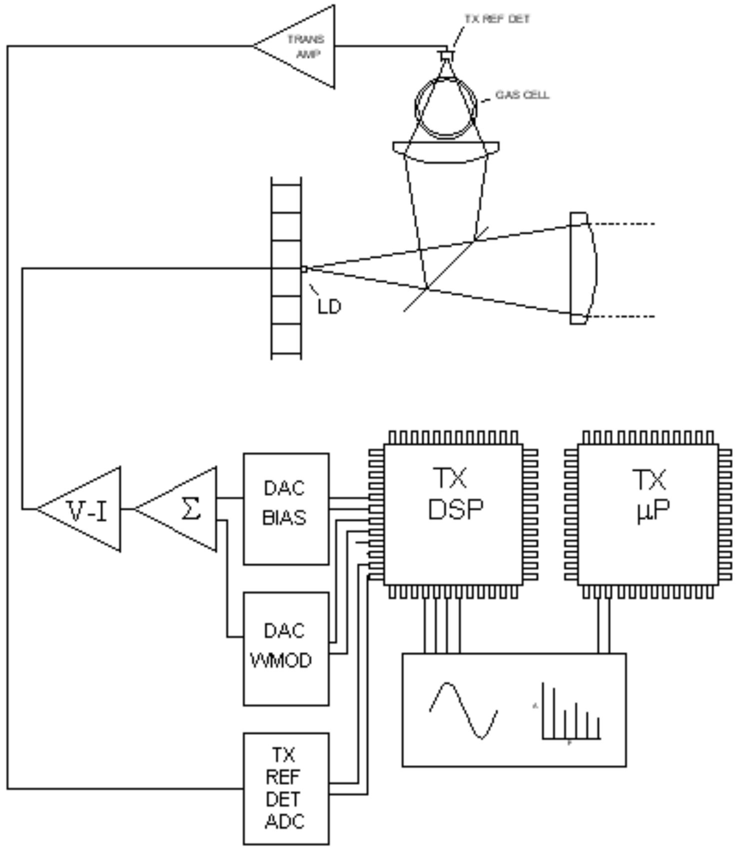
A Harmonic Fingerprint is a specific set of harmonic components introduced by target gas absorption where the relative amplitudes and phases of the components are known and specific to the target gas absorption line that is being scanned (Figure 1)

Figure 1. Example of a Harmonic Fingerprint Produced by Scanning a H_2S Absorption Line at 1589.97nm



Significantly, unlike in conventional LDS systems, there is no ramp in the drive current applied to the laser diode. However, the mean operating wavelength of the laser diode is constantly and precisely regulated by passing a small fraction of its output through a retained sample of the target gas inside the transmitter (Figure 2), then measuring the resulting signal from a reference detector.

Figure 2. ELDS Transmitter Laser Diode Reference / Locking



Channel

Using the signal from the reference detector channel, the transmitter's microcontroller determines the precise bias and wavelength modulation components that must be applied to the laser diode(s) to ensure absorption of the radiation by a target gas that always produces a unique Harmonic Fingerprint.

HARMONIC FINGERPRINT LOCK

The function of the target gas sample in an ELDS *transmitter* is the continuous verification of conditions that ensure the target gas always produces the required Harmonic Fingerprint. When the laser diode drive conditions are maintained and target gas absorption always produces a Harmonic Fingerprint, the transmitter has achieved a *Harmonic Fingerprint Lock*.

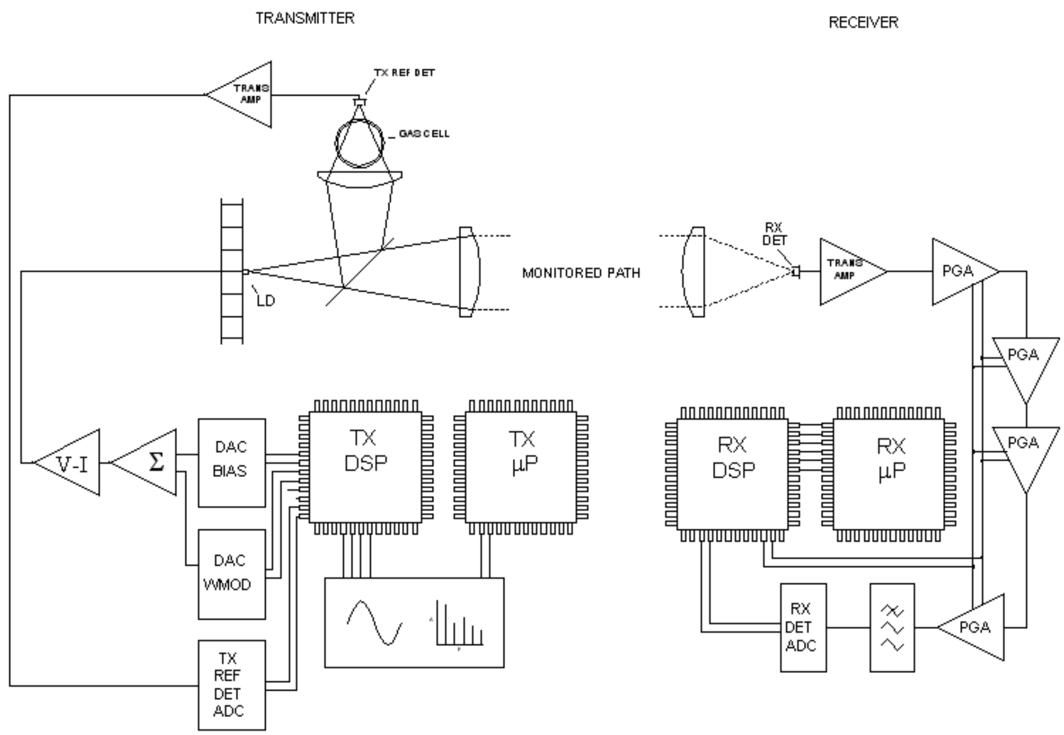
In Harmonic Fingerprint Lock, an ELDS *receiver* can always identify the Harmonic Fingerprint produced by target gas absorption, reliably distinguishing between fluctuations in harmonic levels resulting from a genuine target gas and non-target-gas effects.

The harmonic components in a Harmonic Fingerprint are not a function of the amount of target gas in the retained gas sample, but purely a function of the shape and position of the target gas absorption line. However, when an ELDS transmitter is operating with its laser diode(s) in Harmonic Fingerprint Lock, the size of each Harmonic Fingerprint component is a precise, constant physical property of the target gas. Therefore, both the transmitter and receiver in an ELDS system can identify the precise size of Harmonic Fingerprint components that correspond to any given amount of target gas within the monitored path.

ELDS-BASED OPEN PATH GAS DETECTORS

The typical ELDS-based OPGD system (Figure 3) comprises two units, a transmitter unit and a receiver unit.

Figure 3. A Typical ELDS-Based Open Path Gas Detector



The transmitter sends one or more beams of ELDS modulated laser diode radiation through the line-of-sight path to be monitored for the presence of target gas(es). The transmitter uses its retained target gas sample to maintain Harmonic Fingerprint Lock of its laser diode(s), ensuring false-alarm free identification of target gas(es) in the monitored path. If any target gas is present, the receiver measures the size of Harmonic Fingerprint components. Determining the amount of target gas, the receiver sends an appropriate signal to the control room / system to initiate alarms or trigger the mitigation routines.

FUNCTIONAL TESTING OF AN ELDS-BASED OPGD USING ELECTRONICALLY SIMULATED GAS

Simulated gas detection is a proprietary technique for the on-command, electronic simulation of the presence of target gas in an ELDS-based gas detection system without the need for direct unit access, or introduction of test gases.

The transmitter in an ELDS-based OPGD synthesizes laser diode drive waveforms that include Harmonic Fingerprint components corresponding to a quantity of target gas. When the laser diodes in an ELDS transmitter are driven by waveforms, including the target gas Harmonic Fingerprint components, their optical outputs include the Harmonic Fingerprint components *just as if they had been introduced by genuine optical absorption by the amount of target gas being electronically synthesized*. **This means that an ELDS transmitter can electronically simulate the presence of a specific quantity of target gas in its monitored path.**

Synthesized Harmonic Fingerprint components are physically indistinguishable from those produced by genuine target gas. An ELDS transmitter linked to a control room / system can simulate the presence of a given amount of target gas in its path. By simply comparing a simulated gas signal from the receiver it is easy to functionally test an ELDS detector.

ADVANTAGES OF FUNCTIONAL DETECTOR TESTING WITH SIMULATED GAS METHOD

Simulated Gas functional detector testing offers significant advantages compared to the techniques currently used to test fixed gas detectors in the field:

1. Eliminates the need for operators to generate, handle or apply hazardous gases to remote detectors.

2. Eliminates the need for direct physical access to detectors for testing. Commands to perform Simulated Gas tests can be sent electronically from any location, with test results monitored electronically.

3. Initiating Simulated Gas detector tests from a control room / system greatly detector testing logistics.

4. Simplicity encourages more frequent testing, and risk reduction.

5. Detectors installed at unmanned facilities can be functionally tested remotely, both assisting with de-manning and gas detector function verification prior to personnel visits.

6. Reduced operation and maintenance costs.

Additionally, these different detector functional test methodologies include control room administration and data logging using HART or RS-485 MODBUS, or a local operator in the field with a handheld PDA.

If the Simulated Gas testing process uncovers a safety critical degradation of the system's performance, the system will issue its fault signal to the control room.

CONCLUSION

Enhanced Laser Diode Spectroscopy (ELDS) technology in an open path gas detector offers improved fixed gas detector performance, safety integrity, and reduced maintenance. ELDS is comprised of proprietary Harmonic Fingerprints and Simulated Gas testing techniques. Harmonic Fingerprints produced by target gas absorption along a monitored path enable new levels of sensitivity, and can reliably distinguish between genuine target gas and non-target-gas effects, thus reducing the negative repercussions of false alarms while improving detection capability for general plant safety.

Gas detector functional testing, the bane of operators responsible for maintaining conventional fixed gas detector systems but essential for ensuring the safety integrity of an entire system, is made simple and effective with a patented simulated gas functional test method built into an ELDS OPGD. This method provides operators with the means to perform remote, on-command functional testing of an ELDS gas detector more easily, safely and less expensively than with traditional laser diode spectroscopy gas detector technologies.

REFERENCES

1. Webster, C., Method and apparatus for enhancing laser absorption sensitivity, US Patent 4,684,258, 1987
2. Silver, J.A.and Stanton, A. C., Laser absorption detection enhancing apparatus and method, US Patent 4,934,816, 1990

AUTHOR BIO:

Lee Richman - Senscient Managing Director

Lee Richman, the founder of Senscient is a recognized authority on infrared gas detection with 18 years experience in the design and manufacture of products using advanced electro-optic technology. Additionally, Mr. Richman has lead in the design, manufacture and support of a wide range of products and technologies including infrared gas detectors, videophones, acousto-optic spectrum analysers and medical diagnostic instrumentation. Lee has been awarded or cited with patents in the fields of gas detection, electronic warfare and video-telephony.

Between 1994 and 1996, he was responsible for starting up the development of infrared gas detectors at Crowcon Detection Instruments, developing their first infrared point detector, Cirrus. He joined Zellweger Analytics in 1996 to head up their Optics team and subsequently led the development of their most successful open path gas detector. Up until the end of 2003, when Lee left Zellweger to set up Senscient, he was Zellweger's design authority for optical products and played a major role in ensuring that Zellweger remained the market leader in infrared gas detection.

Lee was born in 1966 and educated in the UK. He has a MEng in Electrical & Electronic Engineering from the University of Bradford.

About Senscient Inc. http://www.senscient.com/

Senscient manufactures and markets advanced gas detection products for industrial safety, risk management, environmental monitoring, and process analysis applications. The patented technology that meets the demands of these applications is "Enhanced Laser Diode Spectroscopy™," a truly revolutionary open path gas detection and measurement technology available in the Senscient ELDS line of open path gas detectors.