VIGO SYSTEM

LASER GAS LEAK DETECTION WITH INFRARED

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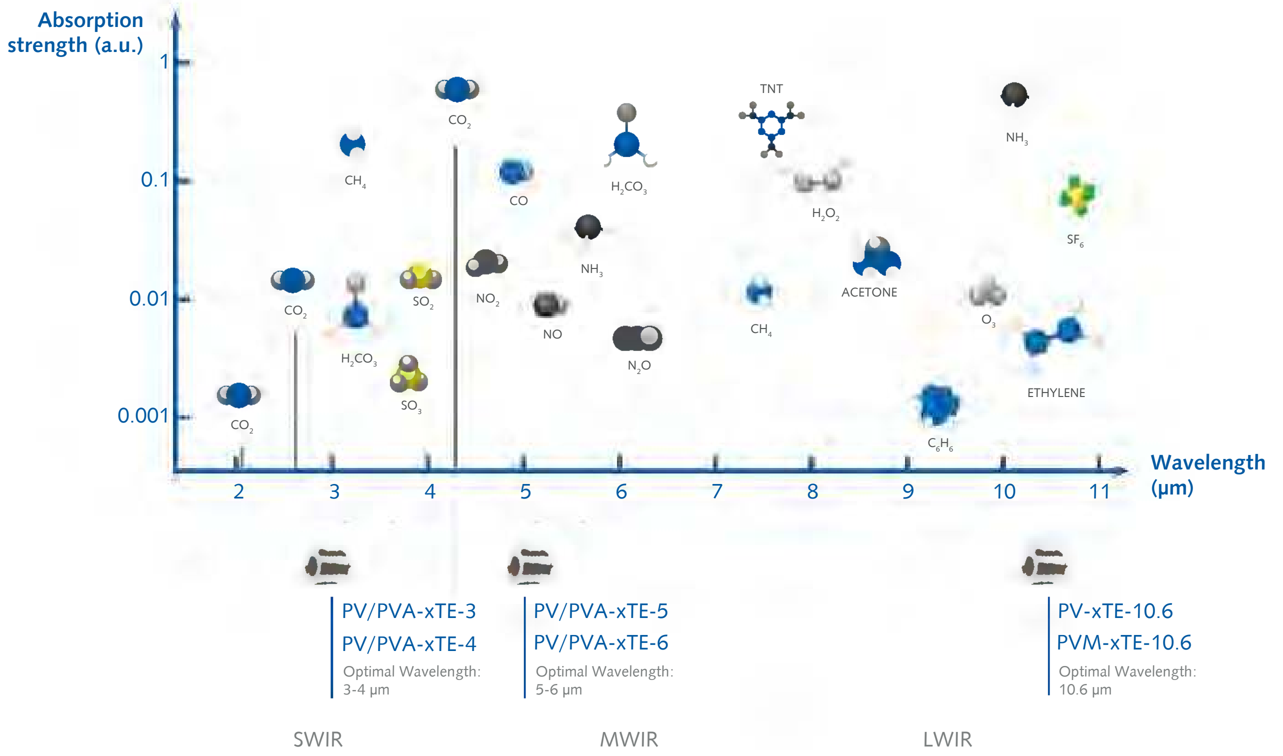
At present, high progress in optoelectronics technology, especially designed for infrared wavelength region (IR), is observed. VIGO System, offering IR detectors, has a great input in the progress. The devices made by VIGO System are not only used in the scientific experiments but they are often crucial elements in industry technologies, mostly in gas analysis systems employing the phenomenon of the optical radiation absorption.

Leak detection of common gases usually deals with a flammable or explosive gas. It means that traditional (i.e., catalytic) leak detection methods are insufficient to successfully detect a leak of a particular gas type.

There is no ideal gas transmission or resource tightness. It means that all gas resources or transmission lines have to be monitored in terms of a gas leakage. Beside traditional gas leak detectors, infrared and laser spectroscopy methods can be used to detect extremely flammable gases. Infrared photon detectors are the major part of the spectroscopy devices. In all spectroscopy gas sensing methods the infrared detectors can be used.

The use of various spectroscopic methods allows to obtain detailed information on the chemical analysis of the leaking gas. Each of the spectroscopy methods is dedicated to different types of concentration measurements. VIGO infrared detectors operate in the wavelength range of 2–16 μm. The wide range of wavelengths allows for the appropriate adjustment of the selected detector sensitivity to the detected gases in the appropriate wavelength range.



Gas spectra with separated lines of the oscillation and rotation can be observed for light particles. In the case of complex polyatomic molecules, usually the oscillation-rotation structure of the spectra is very complex and because of broadening the individual lines overlap and a continuous band is observed.

For some gases particularly relevant for emission and process control, it is necessary to use the mid-infrared range (MIR, 3 μm - 12 μm). This is due to the fact that the gas of interest (e.g., sulfur dioxide, SO_2) has no absorption lines in NIR or, in the case of nitric oxide (NO) and nitrogen dioxide (NO_2), the absorption strength is too low in NIR (in MIR it is up to 1000 times stronger).

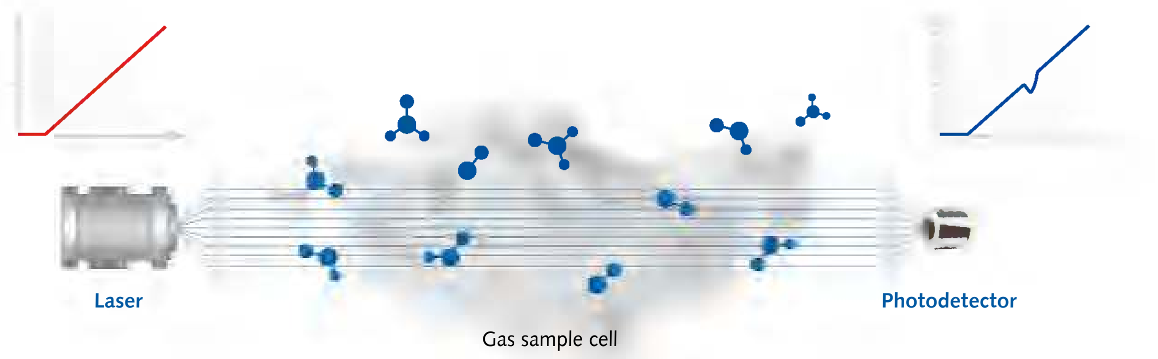


Figure 1
General laser absorption spectroscopy schematics.

TUNABLE DIODE LASER ABSORPTION SPECTROSCOPY

Among the methods of gas analysis, techniques using laser and LED sources are currently the most popular. They ensure a very good signal-to-noise ratio and high selectivity of the radiation used. These solutions are used to detect one selected gas. The most popular systems in this group, such as TDLAS, are characterized by a relatively simple design, very high speed of operation and sensitivity sufficient for many applications. In search of the highest parameters, customers choose CRDS instruments offering detection of even trace concentrations of gases, but, in return, they require high system stability during the measurement.

Tunable Diode Laser Absorption Spectroscopy (TDLAS) is a method used for measuring the concentration of a gas or gas mixture. TDLAS allows to measure a very low concentration of the measured gas (up to ppb). At the same time this method allows to measure temperature, pressure, velocity and mass flux of the gas. The method features are fast response and very high sensitivity.

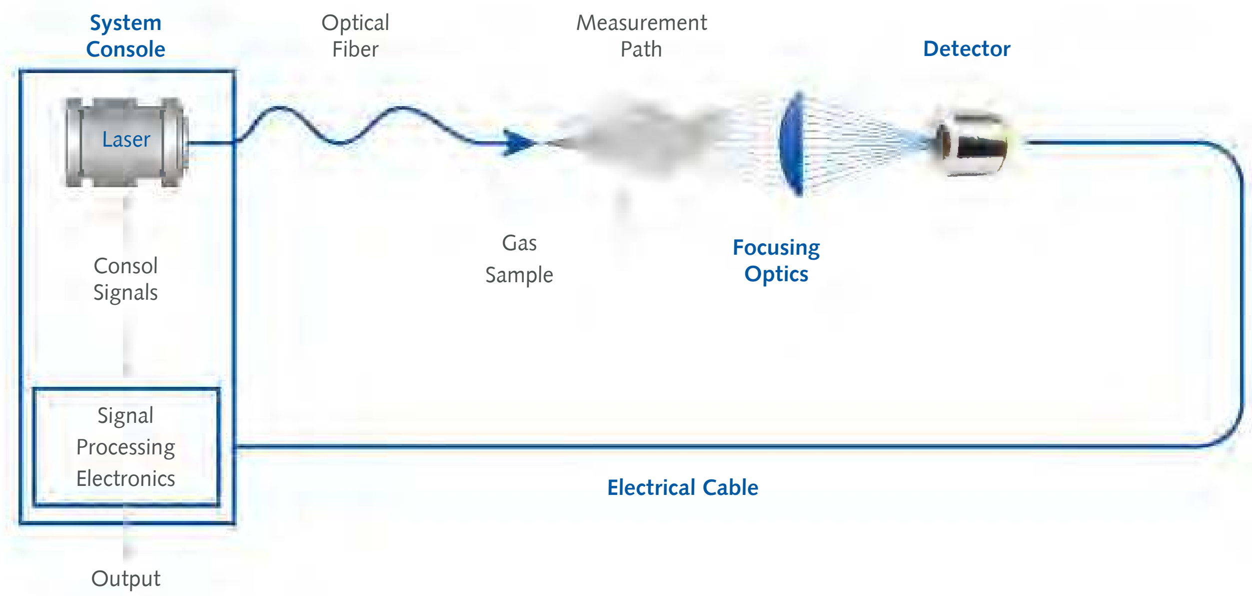


Figure 2
TDLAS absorption spectroscopy schematics.

Beside the laser diode sources, **infrared photon detectors** are commonly used in a TDLAS gas analysis. All features of TDLAS can be maintained by the fast and sensitive photovoltaic VIGO detectors. Below you can find infrared detectors recommended for the TDLAS gas detection systems. **Detector spectral characteristics must be selected for your gas absorption line.**

Table 1.

Selected spectral characteristics for the gas absorption line.

Gas type	Selected absorption line [µm]	Suitable VIGO System detector and modules
Water vapor	2.9 6.3	PV/PVA-xTE-3 PV-xTE-6 AM03120-01
CO_2	4.26, 9.4	PV/PVA-xTE-5, PV-xTE-10.6
NH_3	10.74	PV-xTE-10.6, PVM-xTE-10.6
HCl	3.5	PV/PVA-xTE-4 AM03120-01
HF	2.5	PV/PVA-xTE-3

CAVITY ABSORPTION SPECTROSCOPY

Thanks to methane detection spectrometers based on the CRDS method, it is possible to study natural gas leaks even at a very early stage. Cavity Ring-Down Spectroscopy (CRDS) is a highly sensitive optical spectroscopic technique enabling the measurement of an absolute optical extinction by samples scattering and absorbing light. It has been widely used to study gaseous samples which absorb light at specific wavelengths, and, in turn, to determine mole fractions down to the parts per trillion level.

In particular, devices such as methane detection spectrophotometers based on the said method are used for: monitoring gas transmission lines, analysing defective pipes, forecasting leakages and repairs, risk mapping, emission reduction processes.

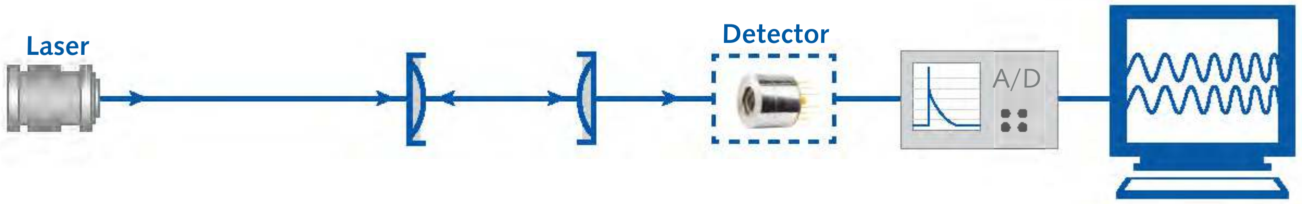


Figure 3

CRDS working principle schematics.

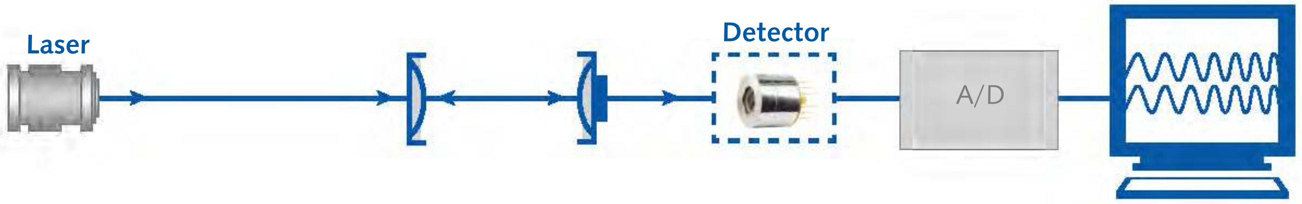


Figure 4

CEAS working principle schematics.

The principle of Cavity Enhanced Absorption Spectroscopy (CEAS) method is based upon a measurement of the decay time of a radiation trapped in an optical resonator with a high quality factor.

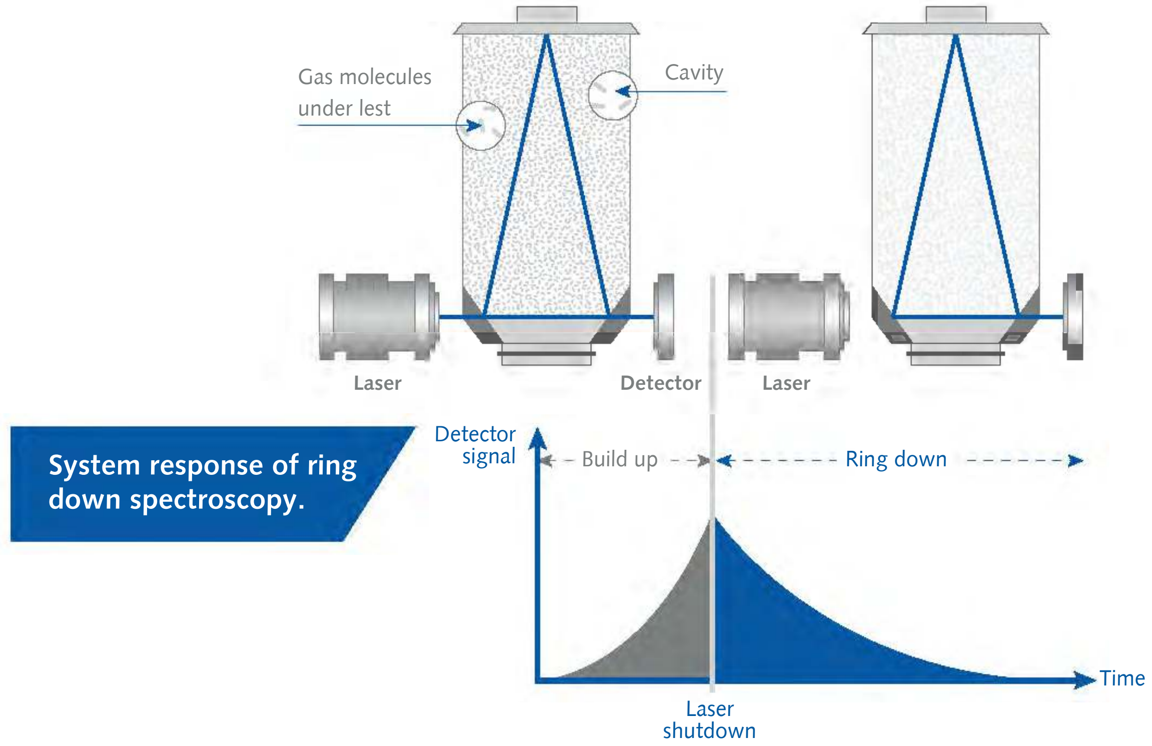


Figure 5

Detailed CEAS working principle schematics.
Left – built up state,
right – ring down state.

In the CEAS method, a pulse of laser light is introduced into an optical cavity (resonator) equipped with spherical and highly reflective mirrors. The pulse is reflected multiple times in the resonator. After each reflection, some of the laser light leaves the resonator due to the lack of 100% mirror reflections. Part of the light coming out of the cavity is registered by a photodetector.

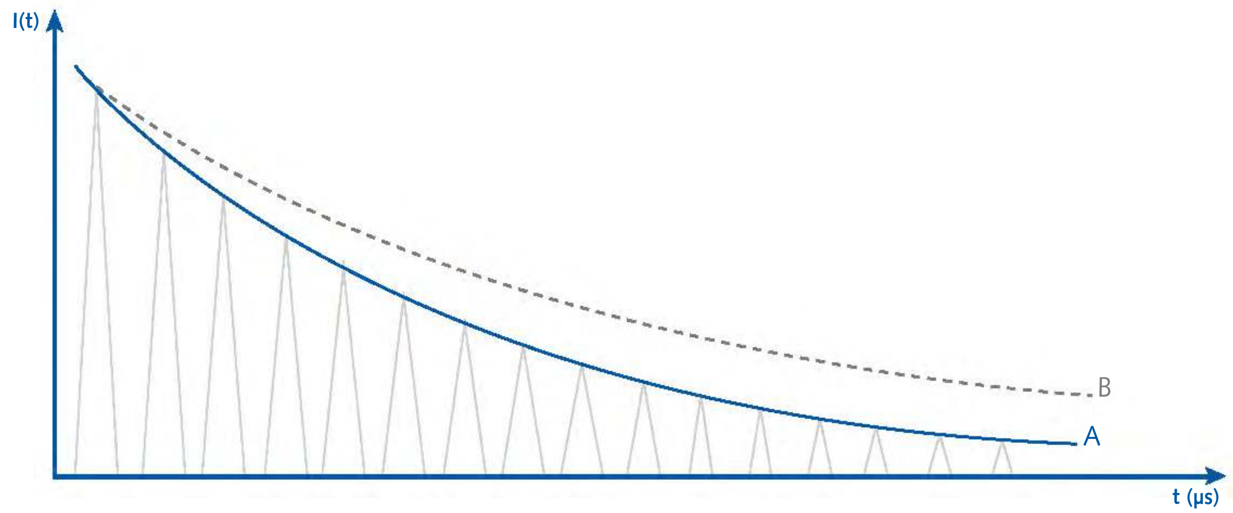


Figure 6

Detected radiation on the output of CEAS.

Methane testing is possible thanks to a strong absorption line for this gas at a wavelength of 3.31 μm. VIGO System detectors are able to detect concentrations of this gas below 50 ppb ± 0.05%.

Table 2.
Detectability of methane by VIGO System detectors.

Gas type	Selected absorption line [μm]	Analysis technique	Suitable VIGO System detector and modules
CH_4	3.31	CRDS/CEAS	PV-xTE-3, PVA-xTE-3

PRACTICAL APPLICATIONS OF VARIOUS GAS LEAK DETECTION

Gas leak detection basic techniques are used as principle methods. They finally have to be applied in end-user practical applications to maintain customer specific requirements. Measurements of gas pipe and natural gas leaks from the ground are the most popular practical applications. Gas leaks could be a static measurement (open path) or on the move - from the sky (air).

Open path spectroscopy has been used to measure hazardous or trace gases from hot point sources such as volcano, industrial, or agricultural facilities. This method is rarely used to measure greenhouse gases from field-scale sources.

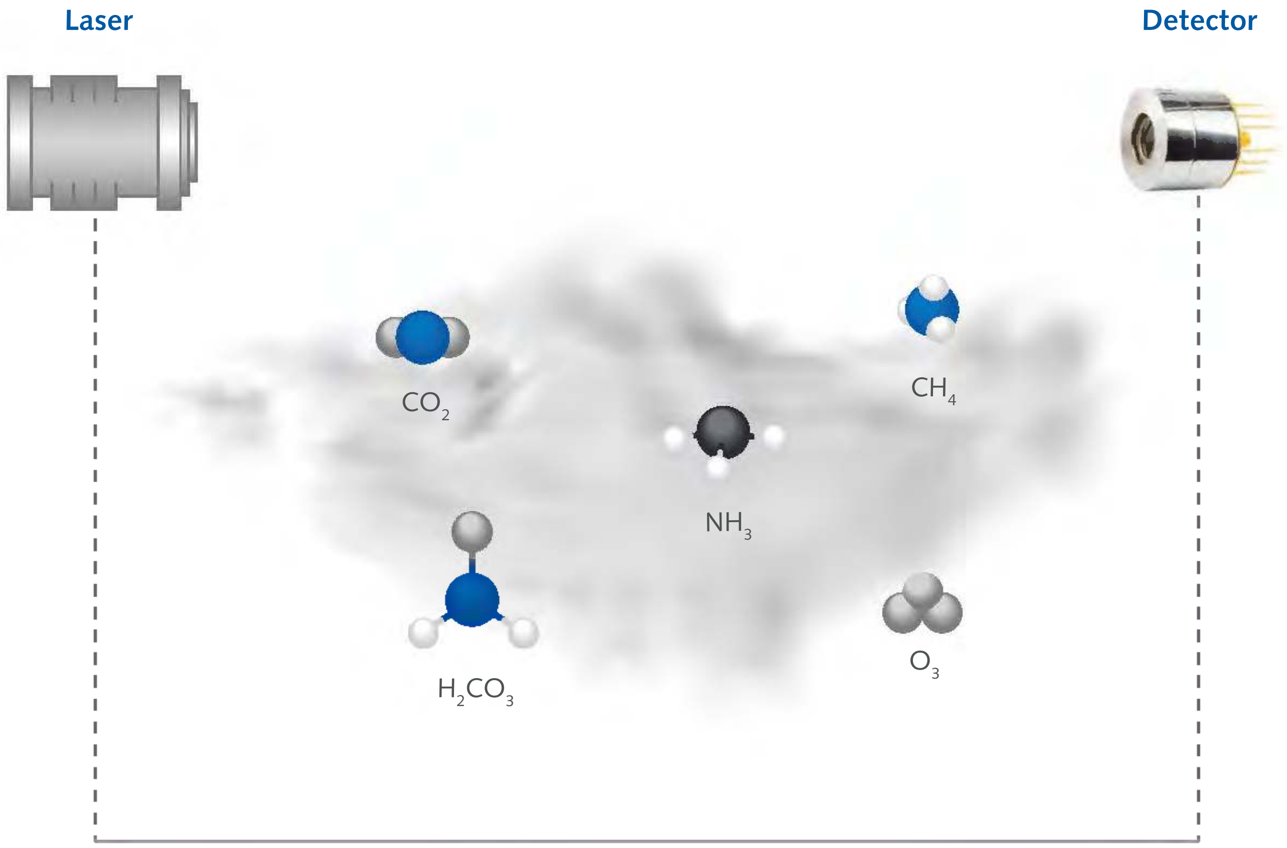


Figure 7
Open Path Laser Detection.

MOBILE MWIR GAS DETECTION

The mobile laser gas detection method consists in detecting and locating a natural gas leak which is methane. For the gas leakage measurement to be effective, the vehicle must be started and travelled a certain distance, then, a chemical-sensitive detector installed in the device will locate the leak. In this case, the methane analyser is installed on a special vehicle, which, thanks to signal transmitters, transmits information about the increased gas concentration directly to the threat monitoring centre.

Figure 8
Mobile laser gas detection.

DRONES WITH LASER SPECTROSCOPY DETECTOR

Thanks to the development of modern technologies, drones equipped with gas sensors can safely provide detailed information on a natural gas leak. Real-time unmanned aerial vehicles reach gas leaks that are dangerous for humans (drone operator). The advantages of monitoring gas leakage by devices in the air are undoubtedly: their small size, so they can get practically anywhere, ease of use and relatively low operating costs of these devices.

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