GAS CAM

PASSIVE REMOTE GAS DETECTOR

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INTRODUCTION

The prevalence of gas detection systems using open-path methods has dramatically increased over the last ten years. By exploiting the mechanism of absorption of infra-red (IR) electromagnetic energy by the gas molecules, it is possible to determine the presence, and quantity, of gas between the detection system and a distant source of IR energy. Each gas has a unique absorption profile or 'fingerprint' **S**uch that the wavelengths at which it absorbs, or emits, depend on its molecular structure. Consequently, detection and quantification of specific gases, while in the presence of other species, are possible.

Nearly all of the currently available open-path systems depend on absorption (as opposed to emission) of energy by the gas and employ an active intense source of IR energy. This requires fixing the source (or reflector if the source is next to the detector) behind the target area and lining up the detector such that it 'sees' the source. Detection is then limited to the pencil-beam between the two ends. For many applications this limitation is not a problem, but for those where the requirement to maintain alignment with a static source is not feasible, or frequent repositioning of the equipment is expected, such a system is not viable. So what is the alternative?

All objects emit IR energy, the amount being primarily dependent on their temperature. The smallest amount of a particular gas that may be detected by analysis of the measured energy profile, partly depends on the relative temperatures of the gas and the background or source (the contrast). When the gas is cooler than the background, it absorbs more of the energy passing through it than it emits, and is seen as a net absorber of energy. When it is hotter, it emits more than it absorbs and is seen in emission. When the temperatures are the same, thermodynamic equilibrium is achieved and there is no net absorption or emission by the gas, i.e. it is spectrally invisible. One analogy of this situation that is often quoted is that of a grey cat standing in front of a grey wall.

As long as there is sufficient contrast it is possible to detect a gas remotely without the need for man-made energy sources. This mode of operation is classified as passive and has many advantages over the active mode. Operation may be by either net absorption or emission of energy by the gas molecules. The detection system can be rapidly positioned and pointed at the scene, or across the path, of interest without the need for time consuming mounting of remote sources and subsequent precise alignment.

By exploiting natural energy sources, the detector can be pointed at virtually anything and, consequently, may operate in a pan and tilt mode. Even looking upward at the sky is feasible. The working field of view can be made relatively wide, by comparison with active systems, which enables a large target sector to be 'viewed'. Area surveillance becomes possible, as does detection from a moving platform such as a vehicle, boat, helicopter or light aircraft. The major drawback compared to active systems is normally reduced sensitivity. This is because man-made energy sources are usually hotter, emitting more energy and providing greater contrast, than naturally occurring ones. However, in those applications where speed of deployment, flexibility and ease of use are paramount, the passive system is most often the preferred and, in many cases, the only option.

METHOD

The passive remote gas detector introduced here is a wide band spectrometer that uses Fourier transform methods operating in the IR (FTIR). Based on the Michelson interferometer, the instrument is a complex electro-optic measurement tool that enables detailed spectral analysis of the received energy. The information made available by such systems allows more than just the ability to monitor a single known gas. A number of selected gases can be monitored simultaneously, or the amount and identity of unspecified gases ascertained. While this capability has been available in the laboratory for a long time, it has required technological advances and innovative development spanning several years to produce a device that is suitable for field deployment. State-of-the-art techniques, devices and materials have been brought together in a robust, portable and simple to use sensor that offers a capability that has been missing from the range of existing gas detection systems. Prime examples of these features include: -

- compact, rugged and light weight mechanical construction
- small integrated colour CCD camera
- miniature high accuracy linear motor
- highly integrated and low-power electronics
- complex data processing algorithms
- high-performance robust optics
- high-resolution colour liquid crystal graphics display (LCD)
- leading-edge semiconductor laser diode
- powerful computing and signal processing facilities

In common with other open-path detection systems, quantification of the gas concentration is in terms of the total amount integrated along the path between the detector and the background. This is unlike measurements made by point sensors and sampling systems that determine local concentration, usually in units of parts per million (ppm) or percentage of the lower explosive limit (%LEL). The equivalent open-path integrated units are normally expressed in parts per million metre (ppm.m) or LEL.m.

The capability to detect reliably and measure the received energy is a function of the hardware configuration. Subsequently determining the presence of a specific gas or mixture of gases from analysis of the received signal relies on the intelligence of the signal processing algorithms and proper use of all *a priori* information. Combination of the two produces a non-intrusive gas detection instrument that can accurately and repeatably derive gas concentrations integrated over the 'viewed' path.

OPERATION

While the features described above have been needed to enable the required functionality, ease of use has also been a major consideration. By incorporating a small video camera within the instrument, pointing the device at the intended target area becomes trivial. Extremely friendly software routines and clear user-interface allow simple operation as, once set up, the system runs automatically. The operator is then provided with a real-time readout of all measurements on a monitor while the system simultaneously time-stamps and archives the data for later analysis or presentation. Self-test and diagnostic routines ensure that the instrument alerts the operator should a fault appear, and internal recalibration is used to maintain the credibility and validity of the measurements. Totally automatic operation, without the need for any user intervention, is also possible. This can be combined with remote data collection via installed cables or optical fibres, the public telephone network (including cellular phones) or direct satellite links where available.

The device is small enough and light enough to be transported by a single operator. It may be mounted on a portable stand such as a tripod, or more permanently secured to a static structure. The feasibility and practicalities of a hand-held or shoulder-mounted version are also being investigated. Whatever the case, this system may be rapidly repositioned around a single site or redeployed at another location. Alternatively, the fixed configuration may be more suitable if the system is to be used for area surveillance in a scanning mode. In many instances both types of deployment may be employed, firstly to identify the existence of a potential problem and subsequently to locate the exact source of the emission. There are clearly numerous ways in which the capabilities of this system can be exploited, highlighting the flexibility of deployment made possible by utilising naturally occurring background energy.

Although specifically designed to enable passive operation, the system is not incompatible with the active mode. Where the contrast is insufficient or the gas spectral characteristics within a region of significant atmospheric attenuation, a hot man-made source may be the answer. In fact, it is not inconceivable that a single device could be operated passively during certain deployment scenarios and then used with an active source for others.

APPLICATIONS

Information gathered from industrial site operators, regulatory authorities and legislative bodies has uncovered a wide range of potential applications for a gas detection system that offers passive and remote capabilities. A large number of these may be divided between two categories - safety or hazard detection where a substantial release may quickly lead to catastrophic failure, fire or explosion; fugitive emissions where more gradual leaks may result in costly loss of product or an excess ambience of a potentially harmful substance. The former requires rapid speed of response but not necessarily a particularly demanding level of sensitivity. The latter may provide a measurement more slowly but will usually require a lower threshold of detection. A single device can meet both of these needs, simultaneously if required, demonstrating the operational flexibility of the instrument.

The working spectral band for the device is between 8 and 14 µm that defines a transmission 'window' through the atmosphere. This range, known as the thermal IR, is also of particular significance to identification of materials by spectral analysis and is often termed the 'fingerprinting' region. A large number of molecules are characterised by absorption of energy within these wavelength limits which means that many gases can be detected. Also, as the predominant source of available energy in this band is from terrestrial objects at ambient temperature, passive detection can be performed during both day and night. Reliable operation over distances of many hundreds of metres is possible in most cases, and for some applications this can be extended to a kilometre or more.

Many organic and inorganic compounds can be seen to absorb energy in the 8 - 14 µm spectral region. Consequently, most of the common families or groups of gases that are of particular interest, such as VOCs (volatile organic compounds) and BTX (Benzene-Toluene-Xylene), may be detected. In fact, unlike spectral analysis in the 3 - 5 µm atmospheric transmission window, the thermal IR allows unique discrimination and identification of most hydrocarbon molecules. Inorganic species such as ammonia are well represented in this spectral band and, to date, only a small minority of suggested detection targets have been outside its scope. Most of those molecules are better observed at shorter wavelengths (the 3 - 5 µm near-IR or the visible / ultra-violet below 0.7 µm). The generic technique that is core to system operation is not wavelength specific, and reconfiguring the device to include optics and a detector that work at the appropriate wavelengths allows the instrument to be used in other regions of the spectrum.

CONCLUSION

A wide variety range of gas detection systems and sensors already exists. From the simple cheap pellistor, via hand-held flame ionisation detector (FID) and active open-path differential optical absorption spectrometer (DOAS), through to the highly complex and expensive LIDAR, the ranges of capability and price are vast. However, there has been a gap in the market where non-invasive operation is needed. The passive remote detection system described here is intended to fill this void and to offer a viable solution to problems previously regarded as insoluble, insignificant or too expensive.

KEY FEATURES

- Remote operation over distances from metres to kilometres
  Point sensors and sampling systems need to come into contact with the target gas molecules.
- Passive operation relying on energy from ambient or natural sources
  Nearly all existing open-path systems are active. These require man-made radiation sources and retroreflectors, requiring critical alignment and limiting operation to less than 500m.
- Detects gases in the 8 - 14 µm atmospheric window, the spectroscopic 'fingerprinting region', allowing unique identification of hydrocarbons as well as a large number of inorganic gases
  Operation in the 3 - 5 µm window makes differentiating between hydrocarbons very difficult and there are a limited number of inorganic gases detectable
- Wide area coverage
  The area coverage of active systems is limited to the narrow beam between the source and the detector, while passive operation enables an expanding target sector to be viewed.
- 24-hour working
  Passive operation in other spectral regions, especially the visible and ultra-violet, is only possible in the presence of sunlight.
- Simultaneous monitoring of several gas species
  Filter and tuned laser methods are single gas specific.
- Rapid response achieved in seconds (depending on application)
  No need for complicated and time-consuming off-line analysis.
- Detection limits down to fugitive leak levels (depending on application)
  Early warning to enable shutdown / evacuation before reaching a critical situation.
- Live video image
  Promotes ease-of-use, clearly showing the target scene during deployment, and allows off-line (recorded) visualisation.
- Potential for pan and zoom capability
  Active systems need to line-up with their source or retroreflector and cannot be 'pointed' elsewhere.
- Compact and rugged instrument design
  System can be quickly and easily transported and repositioned.
- Intelligent signal processing and visual display enabling non-expert operation
  Analysis intelligence can be built in to the signal processing so that the operator can have concentration data presented in an easily readable form.
- Built in self-check and diagnostic functions
  This reduces the possibility of false alarms and catastrophic system failure.
- Simple calibration and performance validation
  Allow regular checks against standards.
- Cost effective