Iain F Howieson, Cascade Technologies, UK

CEM gets the laser treatment

A novel mid-infrared gas sensor that utilizes laser technology has been developed and according to Cascade technologies will offer a wide range of benefits for continuous emissions monitoring applications.

The measurement of gases associated with industrial processing/emissions monitoring has become increasingly important as the need to improve efficiencies in process control and the introduction of legislation governing emissions have come into force. These regulations, many of them derived from the Kyoto Protocol, have spread in developed countries under various acronyms.

Whether called the 'Large Combustion Plant Directive' (LPCD) and the 'Integrated Pollution Prevention and Control Directive' (IPPC) for the UK and Europe or the 'Clean Air Act' in the USA, these new rules being adopted worldwide have had a dramatic impact on industry, most notably in power generation, where continuous emission monitoring (CEM) has become the norm for gases such as nitrogen oxides (NOx), sulphur oxides (SOx), carbon dioxide (CO_2), carbon monoxide (CO) and ammonia (NH_3).

For the past ten years, the measurement of these gases has relied on a suite of different technologies including non dispersive infrared (NDIR) and Fourier transform infrared (FTIR), however, poor sensitivity/selectivity combined with concerns over cross interference and measurement accuracy have meant that these technologies are increasingly struggling to meet industry demands.

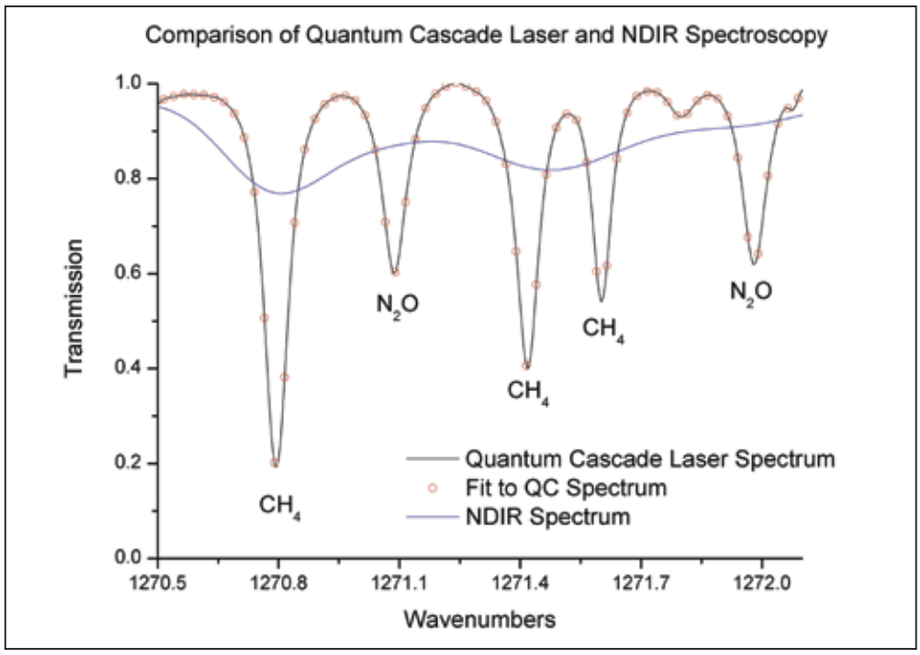


Figure 1: A typical example of the raw spectrum output from recent accreditation tests to MCERTS requirements

"The use of a low noise narrow band optical source affords significantly improved sensitivity, selectivity and immunity to cross interference"

The development of the Quantum Cascade Laser (QCL) has recently been harnessed to create a range of novel mid-infrared gas sensors. Operating at ambient temperatures with high output powers and excellent spectral quality, the QCL sensor has opened up many new applications for laser based gas sensing because of its compact size, robust construction, excellent sensitivity and low power requirements. These include industrial processing/emissions monitoring where recent trials of commercial products in real world applications have demonstrated a step change in performance over incumbent technology.

GREATER SENSITIVITY AND SELECTIVITY

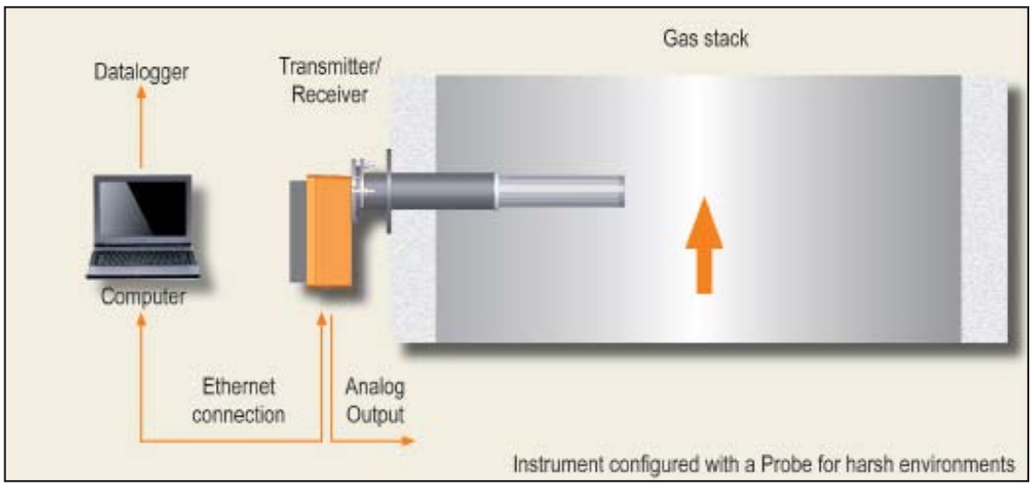
QCL gas sensors rely on infrared optical absorption spectroscopy to determine both the identity and quantity of gases. Absorption spectroscopy is a commonly used and widely understood technique, which is currently applied to many gas sensing technologies, including NDIR and FTIR. The use of a low noise, narrow band optical source such as the QCL, however, affords major advantages including significantly improved sensitivity, excellent selectivity, immunity to cross interference and fast response time. Novel patented methods for further exploiting QCLs for gas detection have recently been developed by researchers at Cascade Technologies, which give the technology additional advantages, including simultaneous measurement of multiple gases and the ability to make over a hundred thousand measurements per second. This helps deliver a wide environmental operational envelope and immunity to turbulence and vibration both of which are key to providing step changes in performance in a real world environment.

A typical example of the raw spectrum output from recent accreditation tests to MCERTS requirements is shown in Figure 1. Also shown in this figure is a spectrum recorded with a low-resolution NDIR technique typically associated with traditional technology.

The QCL gas spectrum clearly shows individual absorptions associated with multiple gases including methane (CH_4) and NOx. This is in stark contrast to the conventional measurement, which cannot pick out the individual gas signatures because of its inherent low resolution.

Cascade Technologies further exploits the high resolution of its QCL source to derive gas concentration from theoretical first principles as set out by the Beer-Lambert law. This is demonstrated by the theoretical spectrum generation for the same wavelength region also shown in Figure 1.

The excellent fit between measured and theoretical spectra enables both the identification and quantification of complex gas mixtures to be derived from first principles. Since these principles do not change with time, calibration remains both fixed and repeatable from one sensor to the next. This ability to directly relate the spectral output to long established theoretical



The QLC gas sensor is immune to cross interference, has high sensitivity, ultra-fast response time and real-time multiple gas analysis

principles also removes the need for correction factors for cross interference, linearity, temperature, pressure and zero and span drift.

COMMERCIAL PRODUCT DEVELOPMENT

A monitoring range, which is claimed to be the world's first commercially available compact and robust QCL based gas sensor developed specifically for industrial applications, was recently launched by Cascade Technologies.

The monitoring product can be configured for both extractive and *in situ* measurement; however, long standing concerns regarding representative measurement with extractive techniques has meant that in situ measurement has become the methodology of choice. Stack conditions including gas temperatures ranging from 50 °C (wet stack) up to 150 °C (dry stack) with external ambients up to 70 °C are typical, and have been given due consideration in the design of the sensor and *in situ* probe.

The sensor has been developed around an all solid-state technology platform with no moving parts to ensure that both industrial life-time and robustness expectations are easily met. The QCLs are semiconductor devices not dissimilar to those that might be found in CD/DVD players/recorders. Cascade has worked in collaboration with several laser manufacturers including a global leading player in the telecoms sector ensuring that all the quality systems and manufacturing processes associated with that industry have been successfully transferred to QCL production. The consequence of these efforts is an extrapolated lifetime of greater than 20 years.

Weighing less than 10 kg and shoe box sized in dimensions, the compact sensor is controlled from a centralized PC via either a private or existing secure network. The control PC can communicate simultaneously with any number of sensors allowing large scale infrastructure to be mapped out. LAN and power connections also have the additional benefits of removing the limitations, costs and reliability concerns of heated gas sample lines.

Each sensing unit can hold up to four lasers allowing full user configurability in terms of gas species measurement, detection range and sampling rate at each individual measuring point. The table below shows a typical configuration for CEM applications.

Data from each sensing unit is stored centrally at the control PC, however modbus communication and 4-20 mA output to other PC's and/or dedicated data-loggers are also provided, and thus enables a single and secure point of data collection for legislative compliance.

QCL GAINS ACCREDITATION

As with all new technologies it is vital to prove that it can meet the rigorous performance and environmental requirements associated with legislated markets. The monitoring product range has recently passed all the accreditation requirements for marine applications based on MCERTS testing protocol. This has resulted in the world's first accredited QCL product for legislated markets.

Following these accreditation tests the QCL product has gone on to demonstrate that it can meet the preliminary testing requirements as set out by the recently introduced MCERTS tests revised in line with the new European standards. These tests were performed at the UK standards lab, the National Physical Laboratory (NPL). Unlike conventional sensor technology all tests completed at the NPL MCERTS facility were passed without any zero, span, pressure, temperature or cross interference correction. Again it is believed that this is a world first. The graphs overleaf provide example test results for linearity, cross interference and drift for gases including NO, NO_2, CO, CO_2, CH_4 and nitrous oxide (N_2O).

The sensor is now undergoing field trials and has been used in CEM applications at coal fired power stations in the UK for six months. These trials will continue and be extended to gas fired power stations later this year.

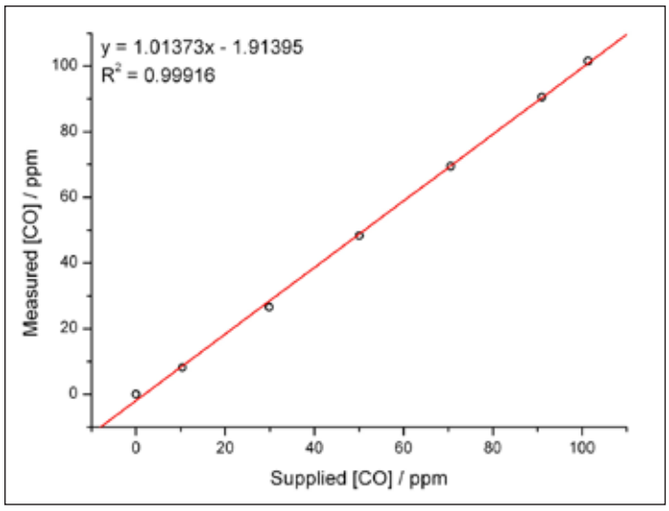
STEP CHANGE IN CEM PERFORMANCE

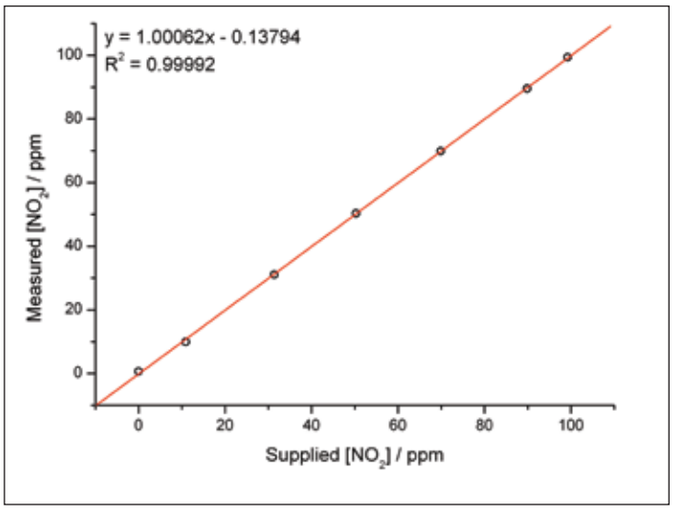
The development of the QCL has recently been harnessed by industry to create a range of novel mid-infrared gas sensors. Operating at ambient temperatures with high output powers and excellent spectral quality the QCL sensor has opened up many new applications for laser based gas sensing because of its compact size, robust construction, excellent sensitivity and low power requirements.

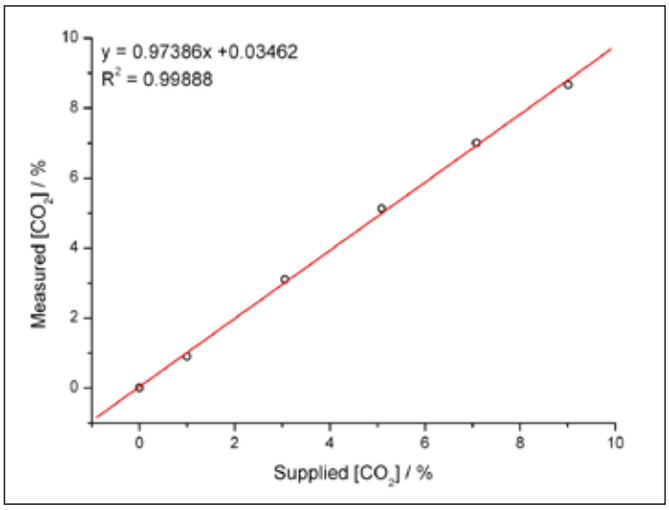
TYPICAL PERFORMANCE CONFIGURATION OF CASCADE'S CEM PRODUCT

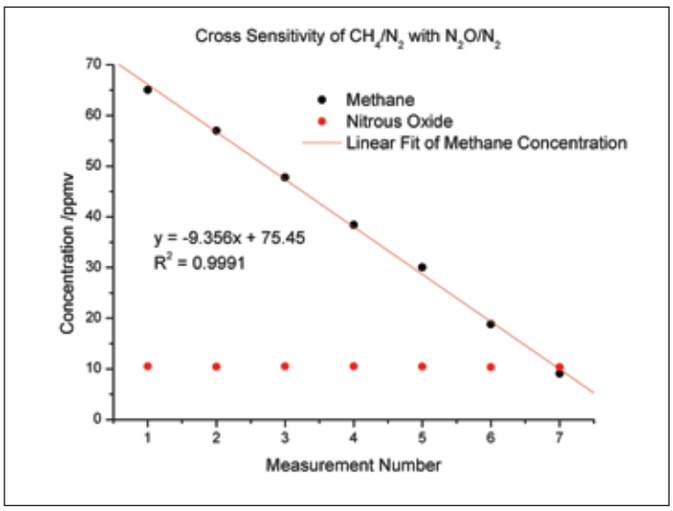
Gas	Range 1	Range 2
NO (ppmv)	0-100	0-2000
NO_2 (ppmv)	0-10	0-200
CO (ppmv)	0-100	0-1000
CO_2 (%)	0-5	0-20
SO_2 (ppmv)	0-200	0-200
NH_3 (ppmv)	0-20	0-20
H_2O (%)	0-5	0-30

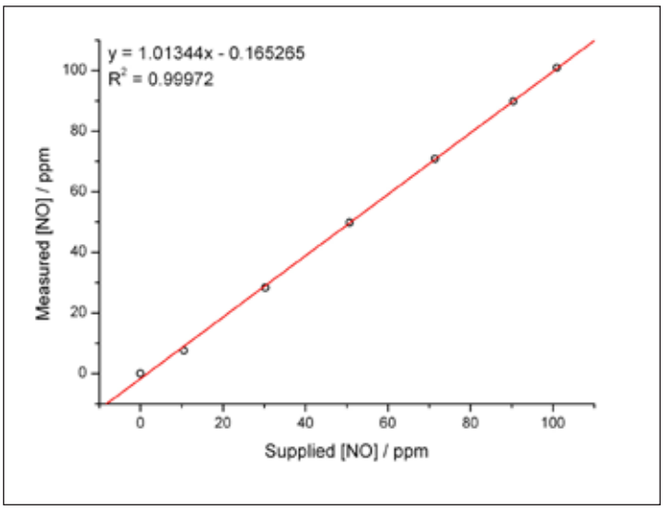
Note: Both gas species and measurement range can be configured for application requirements.

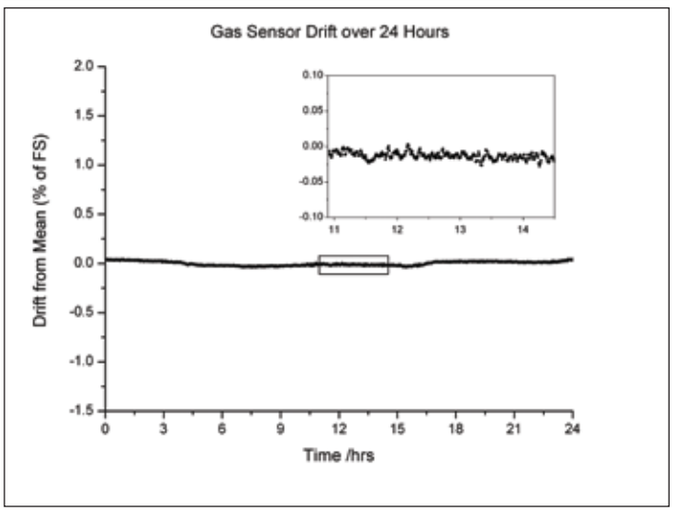












Top to bottom: Typical results for CO (0-100 ppm); CO_2 (0-20 per cent); and NO (0-10 ppm) linearity

Top to bottom: Typical results for NO_2 linearity; N_2O cross interfernce; and gas sensor drift (24 hour period)

Recent accreditation of this product following MCERTS protocol has been achieved without zero, span, pressure, temperature or cross interference corrections. This is believed to be a world first and should deliver a step change in performance over incumbent technology in CEM applications.

Iain Howieson is chief technology officer and managing director at Cascade Technologies.

For more information on the QCL gas sensing product range and Cascade Technologies visit www.cascade-technologies.com

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