Recent advances of mid–infrared compact, field deployable sensors: principles and applications

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The recent development of compact interband cascade lasers (ICLs) and quantum cascade lasers (QCLs) based trace gas sensors will permit the targeting of strong fundamental rotational-vibrational transitions in the mid-infrared which are one to two orders of magnitude more intense than transitions in the overtone and combination bands in the near-infrared. This has led to the design and fabrication of mid-infrared compact, field deployable sensors for use in the petrochemical industry, environmental monitoring and atmospheric chemistry. Specifically, the spectroscopic detection and monitoring of four molecular species, methane (CH_4) [1], ethane (C_2H_6), formaldehyde (H_2CO) [2] and hydrogen sulfide (H_2S) [3] will be described.

CH_4, C_2H_6 and H_2CO can be detected using two detection techniques: mid-infrared laser absorption spectroscopy (LAS) using a compact multi-pass gas cell and quartz enhanced photoacoustic spectroscopy (QEPAS). Both techniques utilize state-of-the-art mid-IR, continuous wave (CW), distributed feedback (DFB) ICLs and QCLs. LAS was performed with an ultra-compact 54.6m effective optical path length innovative spherical multipass gas cell capable of 435 passes between two concave mirrors separated by 12.5 cm. QEPAS used a small robust absorption detection module (ADM) which consists of a quartz tuning fork (QTF), two optical windows, gas inlet/outlet ports and a low noise frequency pre-amplifier. Wavelength modulation and second harmonic detection were employed for spectral data processing. LAS and QEPAS can achieve minimum detectable absorption losses in the range from 10^{-8} to 10^{-11} $cm^{-1}/Hz^{1/2}$. Several recent examples of real world applications of field deployable gas sensors will be described. For example, an ICL based LAS sensor system is capable of detecting CH_4 and C_2H_6 concentration levels of 1 ppb in a 1 sec. sampling time, using a compact, robust sensor architecture. H_2S detection was realized with a THz QEPAS sensor system using a custom quartz tuning fork (QTF) and a QCL emitting at 2.913 THz [4].

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