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

F. K. Tittel, A. Gluszek, A. Hudzikowski, Lei Dong, Chunguang Li, P. Patimisco, A. Sampaolo, V.L. Spagnolo and J. Wojtas

1 Dept. of Electrical & Computer Engineering, Rice University, Houston, TX 77005
2 Dipartimento Interateneo di Fisica, Universita e Politecnico di Bari, Via Amendolo 173, Bari, Italy
3 Institute of Optoelectronics, Military University of Technology, 00-908 Warsaw, Poland
4 Laser & Fiber Electronics Group, Wroclaw University of Technology, 50-370 Wroclaw, Poland
Email: fkt@rice.edu

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 (CH₄) [1], ethane (C₂H₆), formaldehyde (H₂CO) [2] and hydrogen sulfide (H₂S) [3] will be described.

CH₄, C₂H₆ and H₂CO 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/Hz¹/₂. 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 CH₄ and C₂H₆ concentration levels of 1 ppb in a 1 sec. sampling time, using a compact, robust sensor architecture. H₂S 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].

Acknowledgements
F.K. Tittel acknowledges support by the National Science Foundation (NSF) ERC MIRTHE award, the Robert Welch Foundation (Grant C-0586), DOE Monitor Grants DE-AR0000545 & DE-AR0000538. L. Dong acknowledges support by NSF-China (Grant #s. 61275213, 61108030). J. Wojtas acknowledges support by The National Centre for Research and Development, Poland (project ID: 179616).

References