

Mid-Infrared Semiconductor Laser based Trace Gas Sensor Technologies: Recent advances and Applications

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This talk will focus on recent advances in the development of sensors based on infrared semiconductor lasers for the detection, quantification and monitoring of trace gas species and their applications in atmospheric chemistry and industrial process control. The development of compact trace gas sensors, in particular based on quantum cascade (QC), interband cascade (IC) lasers, as well as traditional laser diodes permit the targeting of strong fundamental rotational-vibrational transitions in the mid-infrared, that are one to two orders of magnitude more intense than overtone transitions in the near infrared.

The architecture and performance of four sensitive, selective and real-time gas sensor systems based on mid-infrared semiconductor lasers will be described [1]. High detection sensitivity at ppbv and sub-ppbv concentration levels requires sensitivity enhancement schemes such as tunable laser diode absorption spectroscopy (TDLAS) [2, 3] and wavelength modulation spectroscopy (WMS), photo-acoustic absorption spectroscopy (PAS) or quartz-enhanced-PAS (QEPAS) [2-4]. These spectroscopic methods can achieve minimum detectable absorption losses in the range from 10^{-8} to 10^{-11} $\text{cm}^{-1}/\sqrt{\text{Hz}}$.

TDLAS was performed using an ultra-compact, innovative multi-pass gas cell with an effective optical path length of 57.6 m capable of 459 passes between two spherical mirrors separated by 12.5 cm. A 3.36 μm CW TEC DFB GaSb based laser diode operating at 9.5 °C was used as the excitation source [5-7]. For an interference free C_2H_6 absorption line located at 2976.8 cm^{-1} a minimum detection limit of 130 pptv with a 1 s. acquisition time was achieved. A new state-of-the-art integrated electronic control and data acquisition module was implemented that allowed further significant size reduction without loss of sensor performance.

A QEPAS based sensor capable of ppbv level detection of CO, a major air pollutant, was developed. We used a 4.61 μm high power CW DFB QCL that emits a maximum optical power of more than 1W in a continuous-wave (CW) operating mode [5, 6]. For the R6 CO line, located at 2169.2 cm^{-1} , a noise-equivalent sensitivity (NES, 1σ) of 2 ppbv was achieved at atmospheric pressure with a 1 s. acquisition time. Furthermore, high performance (> 100 mW) 5.26 μm and 7.24 μm CW TEC DFB-QCL (mounted in a high heat load (HHL) package) based QEPAS sensors for atmospheric NO and SO_2 detection will be reported [8, 9]. A 1σ minimum detection limit of 3 ppb and 100 ppb was achieved for a sampling time of 1 s. using interference free NO and SO_2 absorption lines located at 1900.08 cm^{-1} [10,11] and 1380.94 cm^{-1} respectively [12].

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