

Mid-Infrared Quantum Cascade 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 as well as their applications to environmental monitoring, medical diagnostics, industrial process control, and security. The development of compact trace gas sensors, in particular based on quantum cascade (QC) and interband cascade lasers, permits 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 [1].

The architecture and performance of several sensitive, selective, and real-time gas sensors based on near and mid-infrared semiconductor lasers will be described. High detection sensitivity at ppbv and sub-ppbv concentration levels requires sensitivity enhancement schemes such as multipass optical cells, cavity absorption enhancement techniques, or quartz enhanced photo-acoustic absorption spectroscopy (QEPAS) [1, 2]. These three spectroscopic methods can achieve minimum detectable absorption losses in the range from 10^{-8} to $10^{-11} \frac{\text{cm}^{-1}}{\sqrt{\text{Hz}}}$.

Two recent examples of real world applications of field deployable PAS and QEPAS based gas sensors will be reported, namely the monitoring of ammonia concentrations in urban environments and exhaled human breath analysis. The monitoring of ammonia in exhaled human breath using a laser spectroscopic technique can provide fast, non-invasive diagnostics for patients with liver and kidney disorders [3]. The exhaled ammonia concentration measurements are obtained with QEPAS using a compact mid-infrared, continuous wave (cw), high performance, distributed feedback (DFB) QCL from Hamamatsu, Inc. The QEPAS technique is very suitable for real time breath measurements due to the fast gas exchange inside an ultra-compact gas cell. The minimum detectable NH_3 concentration that is achieved with a thermoelectrically cooled, 20 mW, cw, DFB QCL operating at $10.34 \mu\text{m}$ (965.35 cm^{-1}) is ~ 4 ppbv (with a 1 sec time resolution).

References

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