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Mid-Infrared Quantum Cascade Laser based Trace Gas Technologies: Recent Progress and Applications in Health and Environmental Monitoring

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This talk will focus on recent advances in the development of sensors based on infrared (IR) semiconductor lasers for the detection, quantification, and monitoring of trace gas species as well as their applications to medical diagnostics, environmental monitoring, industrial process control, and security. The development of compact trace gas sensors, in particular based on quantum cascade (QC) and interband cascade (IC) lasers, permits the targeting of strong fundamental rotational-vibrational transitions in the mid-IR, that are one to two orders of magnitude more intense than overtone transitions in the near-IR [1].

The architecture and performance of several sensitive, selective, and real-time gas sensors based on mid-infrared semiconductor lasers will be described. High detection sensitivity at ppbv (parts per billion in volume) 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} $cm^{-1}/\sqrt{Hz}$.

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 exhaled human breath analysis and urban environments. The monitoring of ammonia (NH_3) 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 NH_3 concentration measurements are obtained with QEPAS using a compact mid-IR, continuous wave (CW), high performance, distributed feedback (DFB) QCL. 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, 24mW, CW, DFB QCL operating at 10.34 µm (965.35 cm^{-1}) is ~ 6 ppbv (with a 1 sec time resolution). An amplitude modulated photo-acoustic spectroscopy (AM-PAS) technique was employed to monitor atmospheric NH_3 at sub-ppb concentration levels using a 67mW, 10.34 µm CW-TEC Daylight Solutions EC-QCL based sensor platform.

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