Infrared Technologies for Environmental Sensing: Present and Future Opportunities and Challenges

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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, medical diagnostics, industrial process control and security. The development of compact trace gas sensors, in particular based on quantum cascade (QC) and interband cascade (IC) lasers 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 several sensitive, selective and real-time gas sensors based on near and mid-infrared semiconductor lasers will be described [1]. High detection sensitivity at ppbv and sub-ppbv concentration levels requires sensitivity enhancement schemes such as multipass optical cells, cavity absorption enhancement techniques, or photo-acoustic absorption spectroscopy (PAS) [2-6]. These three spectroscopic methods can achieve minimum detectable absorption losses in the range from 10^{-8} to 10^{-11} $cm^{-1}/\sqrt{Hz}$.

Several recent examples of real world applications of field deployable gas sensors will be reported, such as the monitoring of ammonia concentrations in urban environments and exhaled human breath. Monitoring of ammonia in exhaled human breath using laser spectroscopic techniques provides fast, non-invasive diagnostics for patients with liver and kidney disorders [2,6]. The exhaled ammonia measurements are performed with quartz enhanced-PAS (QEPAS) in combination with a mid-infrared, continuous wave (cw), high performance QCL. The QEPAS technique is very suitable for real time breath measurements due to the fast gas exchange inside an ultra-compact QEPAS gas cell. The minimum detectable NH_3 concentration with a thermoelectrically cooled, cw, ~20 mW DFB QCL operating at 10.34 μm (965.35 cm^{-1}) is ~ 4 ppbv with a 1sec time resolution.

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