Recent Progress in Infrared Semiconductor Laser Based Chemical Sensing Technologies

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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.

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} $cm^{-1}/\sqrt{Hz}$.

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 urban environments, such as in the greater Houston area, and exhaled human breath analysis. Monitoring of ammonia in exhaled human breath using laser spectroscopic techniques provides fast, non-invasive diagnostics for patients with liver and kidney disorders. The exhaled ammonia measurements are performed with QEPAS in combination with a mid-infrared, 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 with a thermoelectrically cooled, cw, DFB QCL with an output power of ~20 mW and operating at 10.34 μm (965.35 cm^{-1}) is ~ 4 ppbv with a 1 sec time resolution.

References:

[1] Rice University Laser Science Group website: http://ece.rice.edu/lasersci/

[2] R. F. Curl, F. Capasso, C. Gmachl, A. A. Kosterev, B. McManus, R. Lewicki, M. Pusharsky, G. Wysocki, and F. K. Tittel," Quantum cascade lasers in chemical physics" *Chem. Phys. Lett.*, **487**, 1 (2010)

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