Modular chemical sensor technologies for environmental monitoring and biomedical optical diagnostics

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This presentation will focus on recent advances of mid-infrared quantum cascade laser based sensors for the detection, quantification, and monitoring of trace gas species as well as their applications to environmental monitoring and medical diagnostics. The development of compact trace gas sensors, in particular those based on quantum cascade lasers (QCL) and interband cascade lasers (ICL), permits the targeting of strong fundamental rotational-vibrational transitions in the mid-IR [1]. Trace gas detection at ppbv (parts per billion in volume) and sub-ppbv concentration levels requires sensitivity enhancement schemes such as a multipass optical cell, a cavity absorption enhancement technique, 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} $cm^{-1}/\sqrt{Hz}$.

Three recent examples of real world applications of field deployable PAS and QEPAS based gas sensors will be reported, namely the monitoring of urban environments and ammonia (NH_3) and nitric oxide (NO) concentrations in exhaled human breath analysis. 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 EC-QCL based sensor platform. NH_3 monitoring in exhaled human breath using a laser spectroscopic technique can provide fast, non-invasive diagnostics for patients with liver and kidney disorders [3,4]. Exhaled NH_3 concentration measurements are obtained with a QEPAS based sensor using a continuous wave (CW), thermoelectrically cooled (TEC) distributed feedback (DFB) QCL mounted in a high heat load (HHL) photonics package. 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 24mW, CW, TEC, DFB QCL operating at 10.34 μm (965.35 cm^{-1}) is ~ 6 ppbv (with a 1 sec time resolution). A future design concept for a miniaturized, robust sensor architecture applicable to different green house gases and breath analytes will be discussed.

References:
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