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# Advanced 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 the use of both diode lasers as well as quantum cascade (QC) and interband cascade (IC) lasers for the detection, quantification and monitoring of trace gas species and their application to environmental monitoring, industrial process control, national security and medical diagnostics. Ultra-sensitive, selective and fast response chemical analysis of gases based on molecular absorption laser spectroscopy is a well-established technology.

The architecture and performance of several sensitive, selective and real-time gas sensors based on near and mid-infrared semiconductor lasers will be described. To date we have detected 16 gases ($CH_4$, $H_2S$, $N_2O$, $CO_2$, CO, NO, $H_2O$, $SO_2$, $NH_3$, $C_2H_2$, OCS, $C_2H_4$, $H_2CO$, $C_2H_5OH$, $C_2HF_5$ and $CH_3COCH_3$) at the ppm to ppt level [1,2]. Isotopic signatures of carbon and oxygen have also been observed. High sensitivity requires sensitivity enhancement schemes such as a multipass gas absorption cell, cavity absorption enhancement, or photoacoustic spectroscopy. These methods can measure absorption coefficients as low as $10^{-9}$ $cm^{-1}$ for field deployable gas sensors. A novel technique called Quartz-Enhanced Photoacoustic Spectroscopy (QEPAS), which was first reported by A. Kosterev et al. in 2002 [3,4] will be emphasized. Our progress in QEPAS optimization has now resulted in a 60 fold increase in detection sensitivity as a result of incremental improvements in optical coupling, acoustic design and electronics. QEPAS allows a breakthrough in size, weight, robustness and cost as well as wireless sensor network nodes [5] for laser-based chemical trace gas sensors. Several recent examples of real-world applications including environmental monitoring and nuclear materials processing will be reported.

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