# Laser based Quartz Enhanced Photoacoustics Spectroscopy for Trace Gas Sensing: Principles, Instrumentation and Applications.

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Recent advances in the development of sensors based on the use of semiconductor lasers and photo-acoustic spectroscopy for the detection, quantification and monitoring of both small and large molecular gas species with resolved and unresolved spectroscopic features respectively will be reported. Ultra-sensitive, selective and fast response chemical analysis of gases based on molecular absorption laser spectroscopy is a well-established technology [1-4].

The architecture and performance of several sensitive, selective and real-time gas sensors based on infrared semiconductor lasers will be described. To date we have detected 17 gases ($CH_4$, $NH_3$, $H_2S$, NO, $N_2O$, $CO_2$, CO, $H_2O$, $C_2H_2$, $C_2H_4$, $SO_2$, OCS, $H_2CO$, $C_2H_5OH$, $C_2HF_5$, $CH_3COCH_3$ and $C_6H_{12}O_4$) at the ppm to ppt level [1-4]. 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 in 2002 [5-6] 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 [7] for laser-based chemical sensing applications. Applications include the monitoring of single and multiple gas species for applications in such diverse fields as in environmental monitoring, industrial process control, medical diagnostics and homeland security [2-4].

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