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## **Recent Progress of Semiconductor Laser-Based Infrared Spectroscopic Techniques**

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Recent advances in the development of infrared spectroscopic sources based on the use of both diode lasers and quantum cascade lasers (QCLs) for the detection, quantification and monitoring of both small and large molecular gas species with resolved and unresolved spectroscopic features respectively will be described. 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 [1]. 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 16 gases (CH<sub>4</sub>, H<sub>2</sub>S, N<sub>2</sub>O, CO<sub>2</sub>, CO, NO, H<sub>2</sub>O, SO<sub>2</sub>, NH<sub>3</sub>, C<sub>2</sub>H<sub>2</sub>, OCS, C<sub>2</sub>H<sub>4</sub>, H<sub>2</sub>CO, C<sub>2</sub>H<sub>5</sub>OH, C<sub>2</sub>HF<sub>5</sub> and CH<sub>3</sub>COCH<sub>3</sub>) at the ppm to ppt level [1,2]. 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<sup>-9</sup> cm<sup>-1</sup> for field deployable gas sensors. A novel technique called Quartz-Enhanced Photoacoustic Spectroscopy (QEPAS), which was first reported in 2002 [3,4] will be emphasized. QEPAS allows a breakthrough in size, weight, robustness and cost as well as wireless sensor network nodes [5] for laser-based chemical sensing applications.

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

[2] A. Kosterev, G. Wysocki, Y. Bakhirkin, S. So, R. Lewicki, F. Tittel and R. F. Curl, *Applied Physics B*, 90, (2008) 311-315

[3] A. A. Kosterev, Yu. A. Bakhirkin, R. F. Curl, and F. K. Tittel, *Optics Letters*, 27 (2002) 1902-1904

[4] A.A. Kosterev, F.K. Tittel, D. Serebryakov, A. Malinovsky and I. Morozov, *Rev. Sci. Instr.*, 76 (2005) 043105

[5] S. So, F. Koushanfar, A. Kosterev, and F. Tittel, *Proceedings of Information Processing in Sensor Networks (IPSN)*, (2007) 226-235