Recent Advances and Applications of Semiconductor Laser based Gas Sensor Technology

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Wide Range of Trace Gas Sensing Applications

- Urban and Industrial Emission Measurements
  - Industrial Plants
  - Combustion Sources and Processes (e.g., fire detection)
  - Automobile, Aircraft, and Marine Emissions
- Rural Emission Measurements
  - Agriculture & Forestry, Livestock
- Environmental Monitoring
  - Meteorology/Chemistry
- Chemical analysis and Industrial Process Control
  - Patents, Sensors, Detectors, Mass Spectrometry, Nuclear Safeguards
- Materials Processing & Small Industries
- Spacecraft and Planetary Surface Monitoring
- Ozone Monitoring & Life Support
- Applications in Medicine and Life Sciences
- Technologies for Law Enforcement and National Security
- Fundamental Science and Photochemistry

Quartz Enhanced Photoacoustic Spectroscopy (QEPAS)

Laser beam, power P

\[ S = \frac{q \alpha P}{fV} \]

\[ \text{Absorption} \]

\[ \text{Piezoelectric crystal} \]

\[ \text{Hermon at } f \]

\[ \text{quality factor } Q \]

Comparative Size of Absorption Detection Modules (ADM)

QCL based Quartz-Enhanced Photoacoustic Gas Sensor

QEPAS Characteristics:
- High sensitivity given in ppb
- Wide linear range
- Narrow to broad resonance
- Ultra-small sample volume
- External laser
- High potential for trace gas sensor

QEPAS H₂O signal @ 7306.75 cm⁻¹ (68 ppmv)

QEPAS Ethanol Spectrum between 1825 & 1980 cm⁻¹

Spectroscopy of From 125 (C₃H₆) and C₂H₅OH, with Wide Tunable 8.4 µm CW EC-QCL

QEPAS Performance for 13 Trace Gas Species (Sept '07)

Summary and Future Directions

- Rear and Side-Mirrored Semiconductor Laser based Trace Gas Sensors
  - Compact, robust sensor technology based on novel, high-speed, cavity-dumped, diode-laser technology
  - Fast data acquisition and analysis
  - Detection of 13 trace gases in 100-200 mbar, CH₄, CO, CO₂, NO, NO₂, Ar, Ne, H₂, CO, NO₂, H₂O, N₂, Ar, Ne, H₂O
- New Applications of Trace Gas Detection
  - Cavity-dumped operation for enhanced sensitivity
- Use of gas sensors for industrial process control and automation
- Use of dilution techniques and chemical sensors
- Future Directions and Collaborations
  - Further improvements of existing sensor technology using novel, advanced sensor technology
  - New applications enabled by novel cavity-dumped quantum cascade lasers
  - Development of compact, high-resolution, high-sensitivity sensor systems
  - Development of advanced multiplexed gas sensor networks based on QEPAS

Miniature QEPAS CO₂ sensor (1-2µm) x 2.0 boards

Simulated CO₂ Absorption Spectrum

CO₂ lines in the far infrared range

- Emission of only CO₂
- High sensitivity to CO₂
- Over 10% improvement in sensitivity

**References:**
- "Miniature QEPAS CO₂ sensor (1-2µm) x 2.0 boards." Rice Quantum Institute, Rice University, Houston, TX, USA, Sept. 2-7, 2007.