Industrial applications of pulsed quantum cascade laser analyzers for trace-gas monitoring

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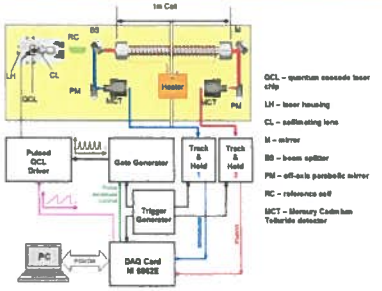
QCL-HPL 2004
Prague, Czech Republic
August 30 – September 3, 2004

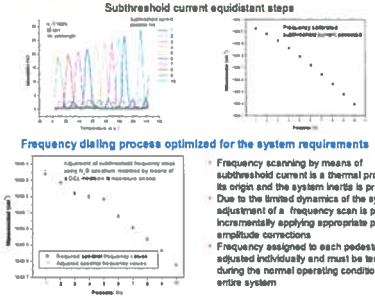
Wide Range of Gas Sensor Applications

- **Chemical Analysis and Industrial Process Control**
  - Power Generation, Pharmaceutical & Food Industries
  - Semiconductor Industry
  - Oil and Natural Gas Industry
- Urban and Industrial Emission Measurements
  - Industrial Plants
  - Combustion Sources
  - Automobile
- Rural Emission Measurements
  - Agriculture
- Environmental Monitoring
  - Atmospheric Chemistry
  - Volcanic Emissions
- Spacecraft and Planetary Surface Monitoring
  - Crew Health Maintenance & Life Support
- Medical Applications

QC Laser Based Gas Sensor Platform

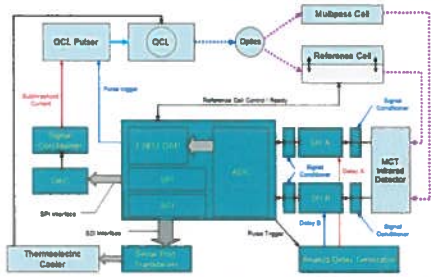


Calibration of Fast Frequency Dialing



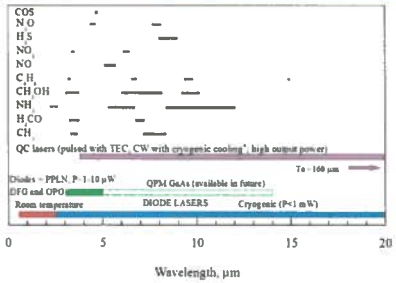
- Frequency scanning by means of subthreshold current is a thermal process in its origin and the system inertia is present
- Due to the limited dynamics of the system the adjustment of a frequency scan is performed incrementally applying appropriate pedestal amplitude corrections
- Frequency assigned to each pedestal is adjusted individually and must be tested during the normal operating conditions of the entire system

DSP Based Pulsed QC Laser Spectrometer*

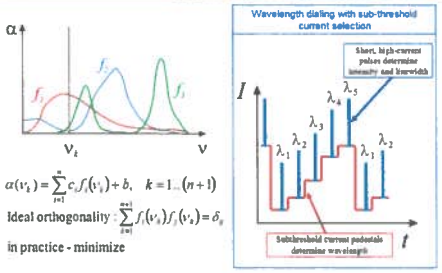


* Joint development by Physical Sciences Inc. & Rice University

Molecular Absorption and Laser Sources



Minimum Number of Points in a QCL Frequency Scan

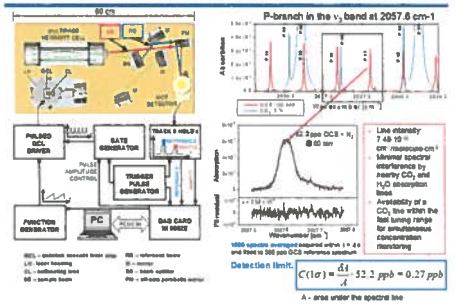


$$a(\nu_k) = \sum_{i=1}^{n} c_i f_i(\nu_k) + b, \quad k = 1 \ldots (n+1)$$

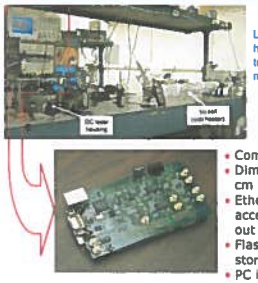
Ideal orthogonality: $\sum_{k=1}^{n+1} f_i(\nu_k) f_j(\nu_k) = \delta_{ij}$

in practice - minimize

QC Laser Based OCS Sensor Architecture



DSP System Controller Card for Gas Sensor Integration



Laboratory setup for simulation of high temperature industrial exhaust trace gases concentration measurements

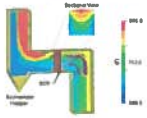
- Compact for portability
- Dimensions: 16.6 cm x 7.6 cm x 3.8 cm
- Ethernet, Serial, JTAG access for control and read out
- Flash memory for long term storage
- PC independent operation
- Up to 12.5 MSPS 12-bit ADC

Specific Issues for Industrial Gas Monitoring with a QC Laser

- Strong fluctuating nonselective attenuation (~70%) by soot particles and gas flow instabilities
- Unresolved individual absorption lines
- Overlapping absorption spectra of different species
- Pulse-to-pulse laser output fluctuations
- Laser frequency drift

- High-power laser, timed detection and very fast scans to freeze fluctuations (minimum number of points scan, high repetition rate)
- Pre-acquired spectral envelopes used in data processing
- Integrated data processing to determine concentrations of ALL the components
- Reference channel for pulse normalization
- Reference absorption cell

Temperature distribution in industrial exhaust

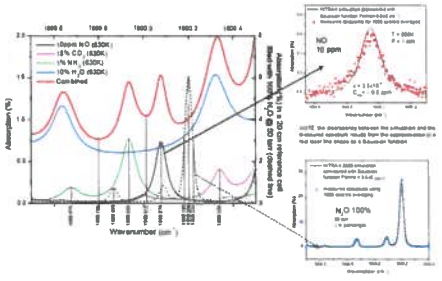


SCR – Selective catalytic reduction, a method of removing NOx from combustion gases using a catalyst and ammonia

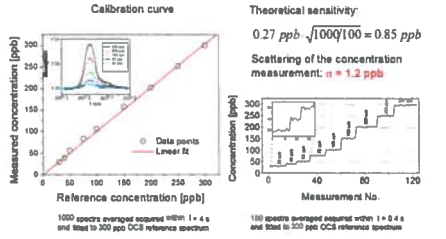
NO and NH_3 must be monitored at a few ppm level

752°F=400°C

Spectral Positions Suitable for Concentration Sampling



OCS Concentration Measurements



1000 spectra averaged acquired within t = 4 s and fitted to 300 ppb OCS reference spectrum

100 spectra averaged acquired within t = 0.4 s and fitted to 300 ppb OCS reference spectrum

Summary

- Two spectroscopic sensors (NO and OCS) based on a pulsed TE cooled DFB QC lasers were presented
- Specific challenges associated with spectroscopic gas analysis of industrial exhaust gases have been identified and addressed
- Preliminary measurements and calibration of a QC-laser based gas sensors were demonstrated
- A concept of rapid wavelength scanning using precise wavelength dialing of a pulsed DFB QC laser was implemented
- A DSP based data acquisition and control system for fast data acquisition and autonomous gas sensor control is currently under test