Nitric Oxide Detection in Breath Using a CW DFB-QCL based QEPAS Sensor

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Outline

Motivation for NO detection:
- Important signaling molecule for physiological processes in humans & mammals (1998 Nobel Prize in Physiology/Medicine)
- Treatment of asthma and (COPD)
- Can determine effectiveness of steroid use to control respiratory inflammation
- Environmental monitoring: ozone depletion, smog and acid rain

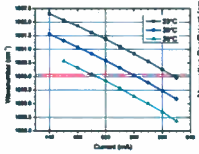
Design of QEPAS Sensor
- QCL characteristics
- Advantages of QEPAS

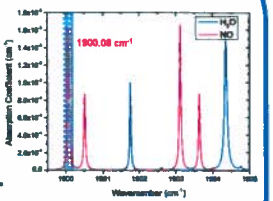
Sensor Design and Evaluation
- Stability and detection limit

Discussion and Summary

5.26 µm DFB-QCL

QCL designed by Hamamatsu
- Access to 1900.08 cm^{-1} at ~580mA @ ~27°C
- Incident optical power ~62 mW





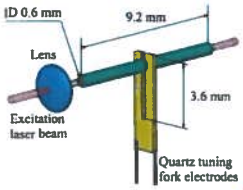
QEPAS

Unique Properties
- Extremely low internal losses:
  - Q~10 000 at 1 atm
  - Q~100 000 in vacuum
- Acoustic quadrupole geometry
  - Low sensitivity to external sound
- Large dynamic range (~10^6) – linear from thermal noise to breakdown deformation
  - 300K noise: x~10^{-11} cm
  - Breakdown: x~10^{-2} cm
- Wide temperature range: from 1.6K to ~700K

Acoustic Micro-resonator (µR) Tubes
- Optimum inner diameter: 0.6 mm; µR-QTF gap is 25-50 µm
- Optimum mR tubes must be ~ 4.4 mm long (~λ/4<l<λ/2 for sound at 32.8 kHz)
- SNR of QTF with µR tubes: ≈30 (depending on gas composition and pressure)

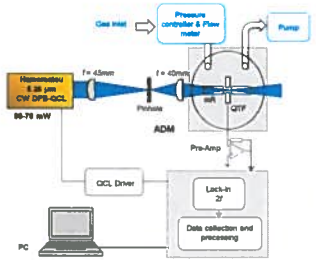
$$S \sim \frac{Q \alpha P}{f V}$$

S – signal strength
Q – quality factor
α – absorption of signal by air
P – pressure
f – resonant frequency of QTF
V – effective volume

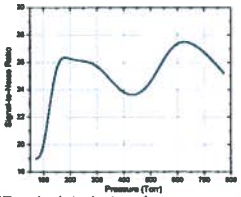


Sensor Design

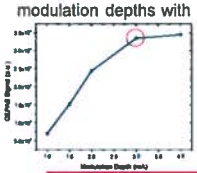
- Employs 2f-WMS spectroscopic technique
- Maximize 2f signal by modulating at $f_0/2$
- Beam diameter in QEPAS cell ~0.25 mm



PICTURE OF CEU & SYSTEM (will add after acetone system is not needed)



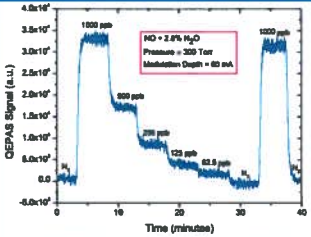
SNR calculated at various pressures at modulation depths with largest signal



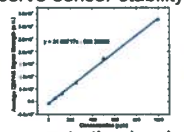
Optimal mod. occurs at the value just before signal saturation

System optimized at 300 Torr and 3 mA modulation depth

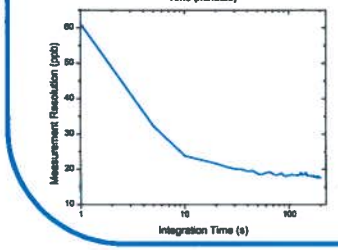
Sensor Evaluation



- Concentration levels of NO in a wet NO:N mixture were varied for a period of 40 minutes
- QEPAS signal monitored to observe sensor stability



$R^2 > 0.99$



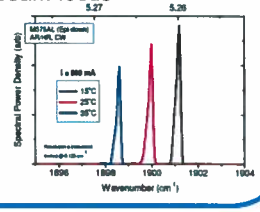
- NO concentration levels in a wet 1ppm NO:N mixture were acquired for a period of 2 hrs
- Allan-Werle deviation plot was created from 2 hr scan of wet 1 ppm NO:N_2

Minimum detection limit is 18 ppb with 100-s averaging time

Discussion and Summary

Detection Limit:
- Improve with higher laser power
- Improve alignment for higher beam focus (less optical fringe noise)

Long-term Drift:
- Most likely line-shifting caused by slight temperature deviations



Future Work

Investigation of broadband absorption species (acetone)

Spectral lines appear in near vacuum

→ WMS cannot be applied

Intensity modulation is necessary

Figure of absorption lines OR of measured acetone signal

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