

RGI
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Environmental Ammonia Monitoring for Urban and Rural Areas of Texas using an EC-QCL Based Sensor Platform

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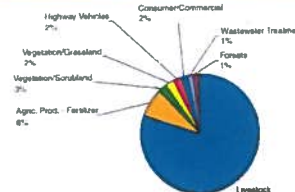
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- Motivation: Environmental monitoring of ammonia (NH₃) using an optical sensor platform
- NH₃ sensor architecture
- NH₃ absorption line selection
- Detection results and long term measurements of NH₃
- Summary

Special acknowledgement to Prof. Barry Lefer (University of Houston) for his hospitality

Ammonia (NH₃) facts

- NH₃ plays an important role in atmospheric chemistry
- Total estimated global emission of NH₃ to the atmosphere is ~ 45 TgN/year
- Industrial and motor vehicles activities can be important in urban areas.
- In the atmosphere, NH₃ reacts with different acid pollutants forming ammonium particulates and aerosols.
- Ammonia is a potential source of atmospheric NO and N₂O.



Ammonia emissions by major source category in Texas [1]

$$\text{NH}_3 + \text{OH} \cdot \rightarrow \text{NH}_2 \cdot + \text{H}_2\text{O}$$

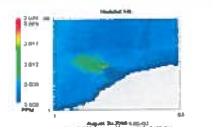
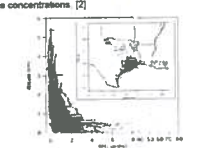
$$\text{NH}_2 \cdot + \text{O}_2 \rightarrow \text{NH} \cdot + \text{HO}_2 \cdot$$

$$\text{NH}_2 \cdot + \text{NO}_2 \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O}$$

[1] R. T. Pavlovic, U. Nopmongkol, Y. Kimura and O. T. Allen, Atmospheric Environment 40, 538-551 (2006)

Estimated ammonia levels for Houston area

- Atmospheric NH₃ concentrations for urban and industrial areas vary between 0.1 and 10 ppbv [1]
- Modeled ammonia concentration for Houston was estimated to range between 1 and 15 ppb [2]
- Typical NH₃ mixing ratios from area sources range from 0.2 to 3 ppbv, but for unexpected industrial accidents or events can increase to 80 ppbv [3]

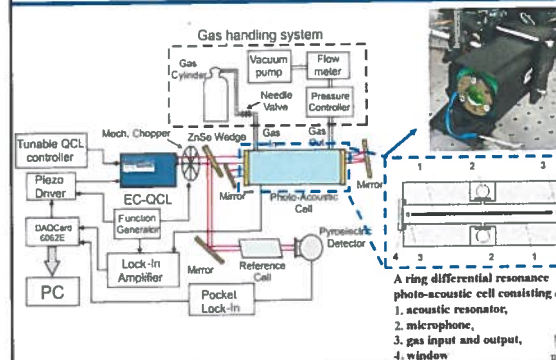



[1] J.H. Seinfeld, S.H. Paes, Atmospheric Chemistry and Physics, John Wiley and Sons, Inc., Hoboken, NJ (2006)

[2] R. T. Pavlovic, U. Nopmongkol, Y. Kimura and O. T. Allen, Atmospheric Environment 40, 538-551 (2006)

[3] Naveckii, B., et al., J. Geophys. Res., 113, D22204, (2008)

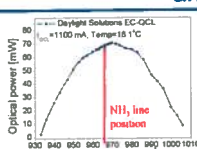
Sensor architecture for atmospheric NH₃ detection




A ring differential resonance photo-acoustic cell consisting of:

1. acoustic resonator,
2. microphone,
3. gas input and output,
4. window

10.34 μm Daylight Solutions CW EC-QCL source and line selection

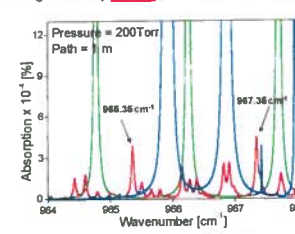


Tuning range and optical power profile for a Daylight Solutions, Inc mid-IR CW EC-QCL system



<http://www.daylightsolutions.com/>


Available EC-QCL power P_{EC-QCL} up to **64 mW (CW)**
Wavelength tunability **73 cm⁻¹** (933 cm⁻¹ - 1006 cm⁻¹)




Pressure = 200 Torr
Path = 1 m

— 1 ppb of NH₃ — 400 ppm of CO₂ — 2% of H₂O



Sensor deployment on top of Moody Tower (University of Houston main campus)



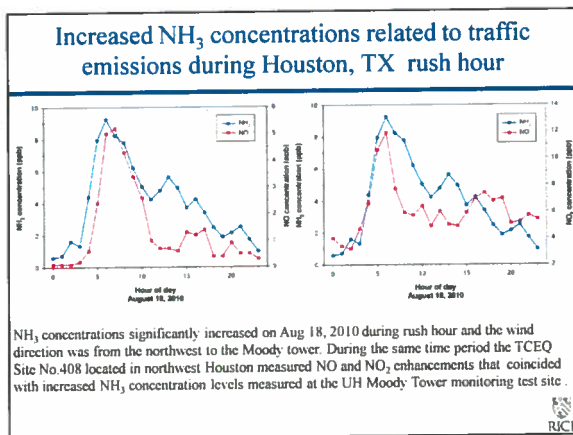
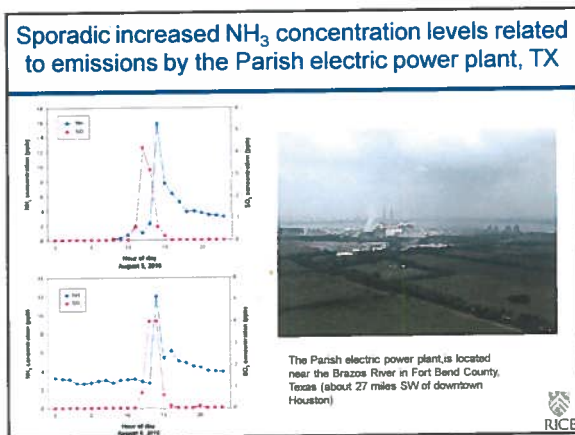
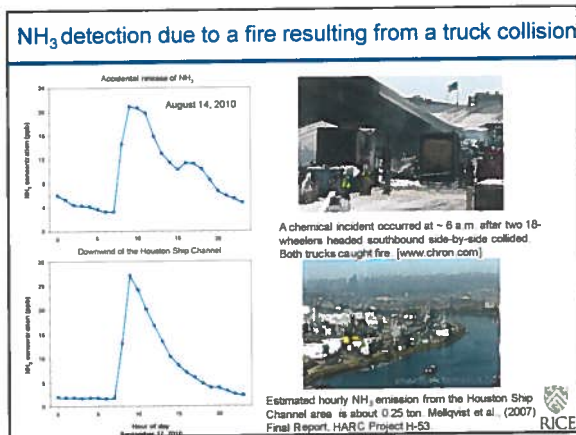
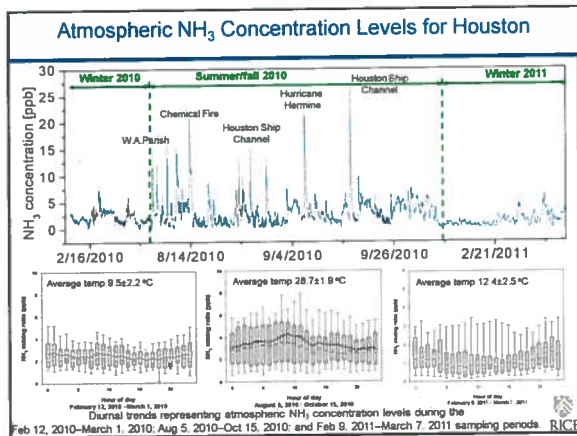
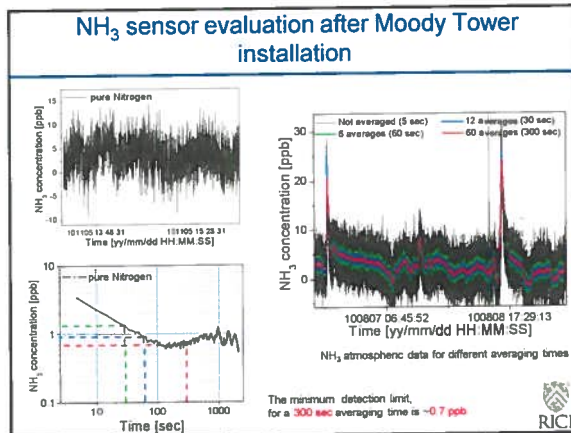
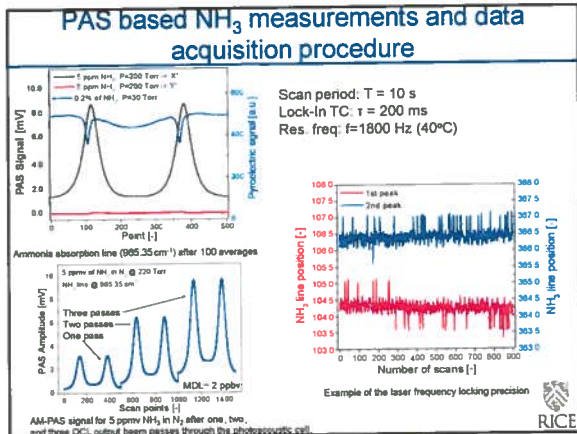
Moody Tower sampling site
University of Houston, TX.

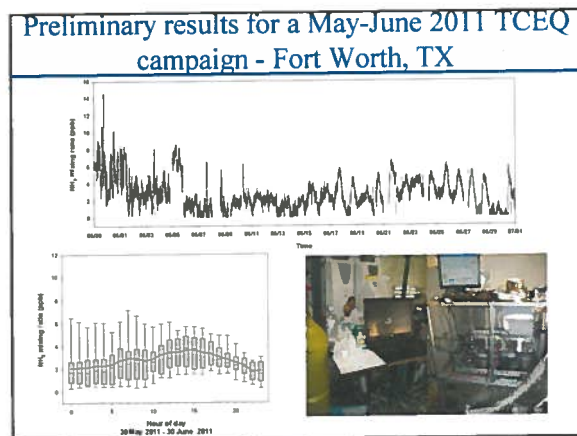
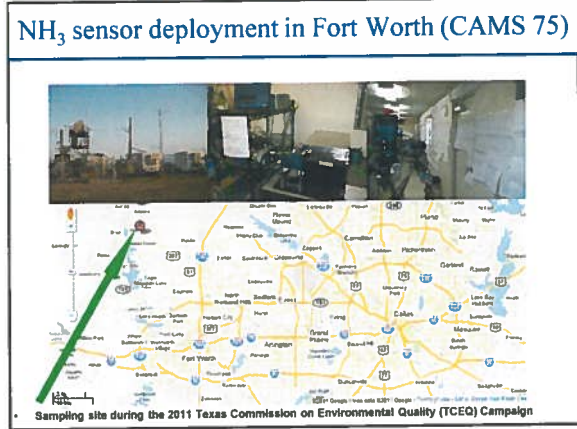
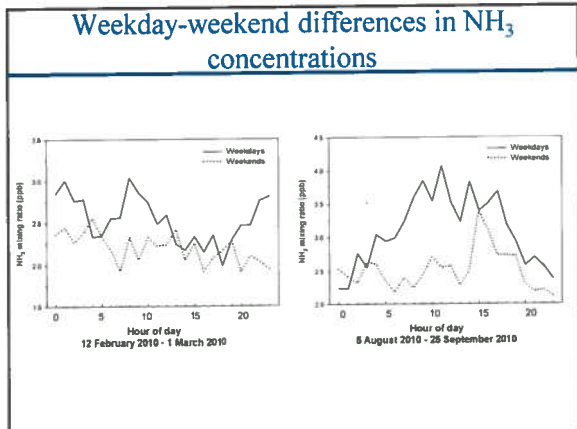


View of Houston downtown from Moody Tower roof

Ammonia sensor installed on the Moody Tower rooftop monitoring site





- ### Summary
- A 10.4 μm EC-QCL based ammonia sensor, employing conventional photo-acoustic spectroscopy, was demonstrated.
 - The minimum detection limit, obtained for the NH₃ absorption line at 965.35 cm⁻¹, was ~0.7 ppb for a 300 sec averaging time.
 - The NH₃ sensor is capable of unattended operation and continuous data acquisition for extended periods of time.
 - Remote access via internet, enabling real-time monitoring of the sensor performance was established.
 - Several unexpected episodes of high NH₃ mixing ratios were observed.
 - The Houston Ship Channel is a significant contributor. However, NH₃ source attribution is influenced by factors such as boundary layer dynamics, meteorology, and the lack of sufficient emission inventory data.
 - The AM-PAS based NH₃ sensor was also field tested at the CAMS75 monitoring site in the Fort Worth/Dallas area, between May 31, 2011 and June 30, 2011, as part of the Summer 2011 Texas Commission on Environmental Quality (TCEQ) Campaign.

