Environmental Gas Sensing

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Motivation

• What issues generate an environmental monitoring need?
  • Health (NO$_2$, NH$_3$ etc)
  • Global Warming (CO$_2$, CH$_4$, N$_2$O)
  • Special Cases (Volcanic gases, Ventilation regulation, Leak detection etc)
Health

- Air Pollution is an increasing concern
  - SO\(_2\) production leads to “acid rain”.

- Major worries now concern air pollution from diesel and petrol cars
  - Britain and France to ban non electrified vehicles from 2040
  - Visible pollution is mainly particulate but NO\(_2\) emissions are a major problem
Health

- Ammonia leaks in processing plants can be hazardous.
- Ammonia levels in intensive farming operations causes damage to the animals (and staff if present).
- Carbon monoxide levels in dwellings are important.
Global Warming

- CO₂ emissions grab headlines but there are other “Greenhouse Gases”

- Methane (CH₄) is 30-80 times more potent than CO₂.
  - Leaks from CNG distribution pipelines
  - Natural emissions—melting of permafrost, undersea emissions
  - Agricultural emissions (animal digestive systems)

- N₂O is 300 times more potent than CO₂.
  - Mainly agricultural emissions
Special cases

- Volcanic eruptions.
- Operating rooms (anaesthetic gases).
Types of Detectors

• The worldwide market is approximately 2B$ and rising steadily.

• Most of the market for gas detectors is as leak detectors.

• Environmental monitoring is a small market.

• Gas detection can be done in many ways, I will categorise them as “Photonic gas sensors” and “others” (mainly electrochemical sensors)
Photonic Gas Sensors

• Gas sensing can be performed using the narrow absorption lines of a gas molecule.

• A laser source can be tuned on and off resonance with the molecule leading to a change in the absorbed power.

• Most sensors operate in the near IR on the harmonics of the absorption line. Accessing the fundamental resonances would yield higher sensitivity but requires lasers operating at 3-10 μ and associated detectors.
Lasers

Gas Sensing Lasers
760 - 2350nm

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Sensitivity

- Since the absorption in the near IR is relatively weak, sensitivity is limited by the optical path length and signal processing systems used.

- A longer optical path length can be achieved in free space systems or in High Q open path resonator systems, typically these systems yield PPM sensitivities.

- Higher sensitivity (PPB) can be obtained by using cavity ring down resonance systems* or photoacoustic spectroscopy.

Portable System

- Absorption in the near IR is relatively weak.

- Sensitivity is limited by the optical path length and signal processing systems used but ppm results are achievable.
Imaging systems

• Imaging arrays operating at the absorption wavelength are expensive.

• Recently methane visualisation has been demonstrated at video rates using a single pixel detector.*

The Marketplace

• For environmental monitoring photonic systems have so far proved too expensive for widespread deployment.

• Cavity ring down or photo acoustic systems with high sensitivity cost tens of thousands of dollars.

• Open path systems can approach $5000 but the market need is perceived to be under $1000.

• The laser used currently costs significantly more than $1000.
Economics

• The market is conditioned by electrochemical gas sensors which work well for some gases and are very cheap, but need regular recalibration or replacement.

• Photonic systems can access nearly all gases but are relatively expensive.

• In large enough quantities lasers could come down significantly in price.

• Since the imaging leak detection systems use the same laser, perhaps this will generate the scale of manufacture required for methane.
How do we get to <$1000?  

- In the US the EPA recently had a “Methane detectors challenge” to try to develop such a system.
- It’s all about volume.
- Regulation - clean air requirements.
- Consumer demand - in home safety.
- Other ideas?