Continuous, regional approach to methane source detection and sizing using dual frequency comb laser spectroscopy and atmospheric inversions

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Overview

Goal: Regional leak detection service covering Oil & Gas infrastructure in 5-30 square mile regions

Leak Detection and Sizing
- To date, ability to find up to 2 leaks
- Ability to approximate source strength
- Coverage of areas up to 20m x 20m

Dual Comb Spectroscopy (DCS)

Averaged 

Frequency Comb Technology

Frequency Comb: a stabilized mode-locked laser, output acts as >100,000 well behaved CW lasers

- Time domain: T = 1/f
- Frequency domain: F(f)

Passively Mode-Locked Laser

Proof-of-Concept Dual Comb Spectrometer

Fieldable Frequency Comb

Our Combs

- Sensitive mode locking
- Stabilized optical table
- >500,000
- Portable DCs
- Large cost reduction
- Replicable for field deployment

Frequency Comb lasers are ready to move out of the laboratory:

- InGaAs detectors
- 0.3 m long package
- Simple reproducible design
- FPGA control electronics

Field Deployment, Table Mountain

Field Site and Deployment:
- North-Central Colorado
- Flat-topped mesa, ~3 x 2 km across
- Few local methane sources
- Variable meteorological conditions
- Methane chambers and flow controllers for testing sensitivity to two very small (8 sccf) leaks
- Wind sensors: Kestrel vanes and 3D anemometers
- Return beam is coupled directly onto photodiode

Retroreflectors (“retros”):
- Corner cube mirrors
- Can be located < 1.2 kilometers from spectrometer
- Refractive telescope launches/releases light
- 20 s beam expander with 3” optics
- Return beam is coupled directly onto photodiode

Measurement Precision:
- 2 ppb along a 1 km beam path in <100 seconds during stable conditions
- Allen deviation shows that measurement precision improves with averaging time
- Noise increases after several minutes due to atmospheric CH4 variability

CH4 Inversions for leak detection

Deployment and Leak Detection Testing at Table Mountain, Colorado

Goal: Detect two 10-15 sccf leak (0.1 - 0.2 kg/hr) within one day

Method: place two 6 sccf leaks in field, sample beams upwind and downwind of leak as well as other potential leak locations (e.g., well pads)

Experiment: Use inverse model to determine presence of two leaks and leak rates

Can we size multiple leaks in an inversion with only one set of beams per well site?

CH4 Measurements

Least-squares fit for leak rate at each well site

Bayesian Inversion for leak rate at each well site, each time step

What if intermittency of leaks is unknown?

CH Enhancements at each leak site

Enhancements observed at no leak sites (well sites 1, 3, and 5) are significantly different from zero

Enhancements observed at leak sites (well sites 2 and 4) are significantly different from zero

Metropolitan conditions on 04/26/2017

Well Site 1 (no leak)

Well Site 2 (leak)

Well Site 3 (leak)

Well Site 4 (leak)

Well Site 5 (leak)

Future Work

- Future Goals
  - Identify industry partners for testing DCS system at production sites
  - Test approaches to finding leak location on well pad to within 5 m
  - Expand applicability of observing system for other types of facilities, natural systems

*Inversion for a single potential point source. Information about shared likelihood of leaks between well & separator (for example) can be incorporated