Open-path Mid-infrared Dual-comb Spectroscopy for Measurement of Ambient Ethane and Propane

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Why Dual-comb Spectroscopy (DCS)?

- Extremely high resolution (0.0067 cm⁻¹)
- Well-suited to outdoor studies
- Can propagate >1 km with spatial coherence
- Fast (20 second) time resolution
- Ability to average for minutes to hours
- Low sensitivity to air path turbulence
- No moving parts
- Broad spectral coverage = multi-species detection (can extract dry mixing ratios)
- Piecewise polynomial baseline removal
- Automatic telescope pointing servo
- Can propagate >1 km with spatial coherence
- Broad spectral coverage = multi-wavebands
- 4.5-5 µm measurements (preliminary)

Here, we demonstrate DCS across long open-air paths in the mid-infrared and show detection of controlled releases of acetone and isopropanol across a 162-m path, measurement of methane and NMHCs across a 1-km path for several days, and preliminary measurements of CO, N₂O, and O₃.

References

Ycas et al. (2019) Optica, 6, 165, Mid-infrared dual-comb spectroscopy of volatile organic compounds across long open-air paths
Ycas et al. (2018) Nature Photonics, 12, 202, High-sensitivity mid-infrared dual-comb spectroscopy spanning 2.6 to 3.2 µm
Wacker et al. (2013), JQSRT, 127, 128, Measurement of hydrocarbons with a dual-frequency comb spectrometer
Coddington et al. (2018) Optica, 5, 341, Dual-comb spectroscopy
Cundiff and Ycas (2017) Rev. Mod. Phys., 89, 325, Coherence: Femtosecond optical frequency combs

Technique

DCS principle

Mid-infrared frequency comb

Open-path DCS

Results

Detection of VOCs

Measurement of ambient NMHCs

1.56 µm generation

1.05 µm generation

1.1 µm generation

1.1 µm generation

5 µm generation

40 mW

10.5 1.10 1.15 Wavelength (µm)

0.0 0.5 1.0 6 mW

0.0 0.2 0.4 0.6 0.8 1.0

Intensity

Intensity

40 mW

0.0 0.5 1.0 1.5

Wavelength (nm)

Wavelength (nm)

Temperature

Temperature

H₂O, CH₄, CH₃OH, and CH₃OCH₃

H₂O, CH₄, CH₃OH, and CH₃OCH₃

Approach

Approach

Optical gas and liquid

Reference

Optical gas and liquid

Reference

Comb 1

Comb 2

Gas sample

Gas sample

Combination

Combination

THz

f₁ (~200 MHz, 0.0067 cm⁻¹)

f₁ (~100 Hz, 0.0067 cm⁻¹)

Δf (~100 Hz)

Δf (~200 MHz)

Δf (~100 Hz)

Δf (~200 MHz)

Δf (~100 Hz)

Δf (~200 MHz)

Δf (~100 Hz)