Fast Detection of Multispecies Liquid Evaporation by Mid-IR Broadband Supercontinuum Source and Upconversion Spectrometer

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Turbulence: fluid motion characterized by chaotic changes in pressure and flow velocity.

Turbulence event:

- Rapid changing;
- Highly irregular;
- Non-directional (difficult to predict);

Why study turbulence:

- Monitoring the process;
- Weather forecast, engineering, environmental monitoring, etc

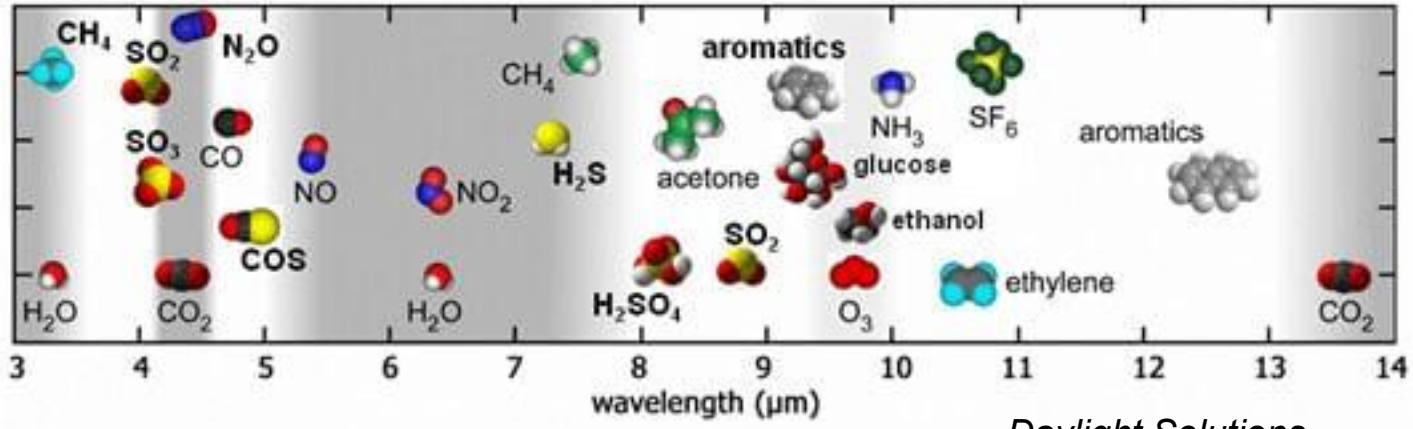
To monitor the turbulence event, we need:

- High sensitivity and selectivity;
- High time resolution;



Mid-infrared broadband absorption spectroscopy

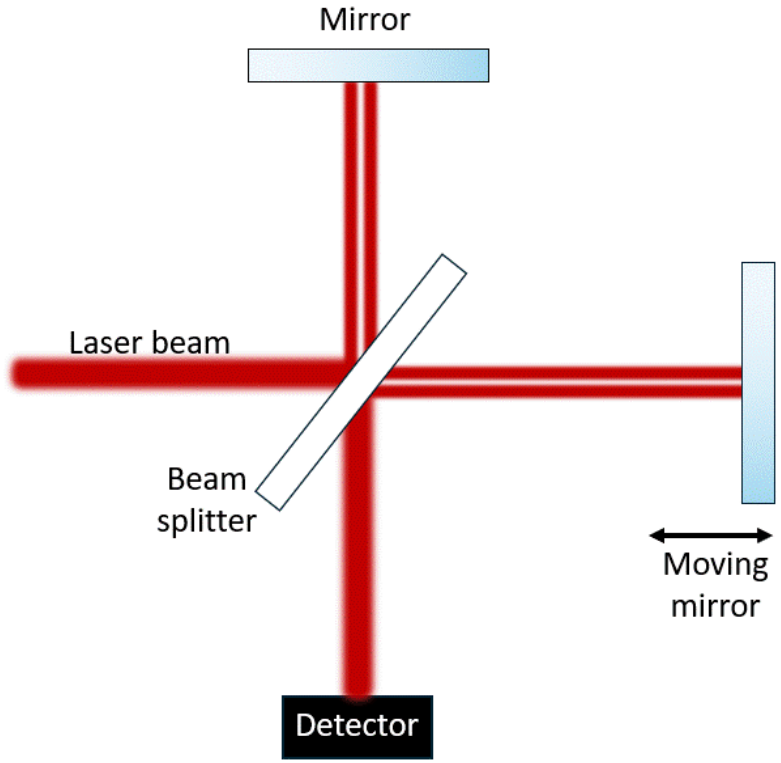
- Various species, strong and distinct absorption lines in mid-infrared region;
- “Fingerprint” of every molecule;
- Broadband allows multispecies detection;

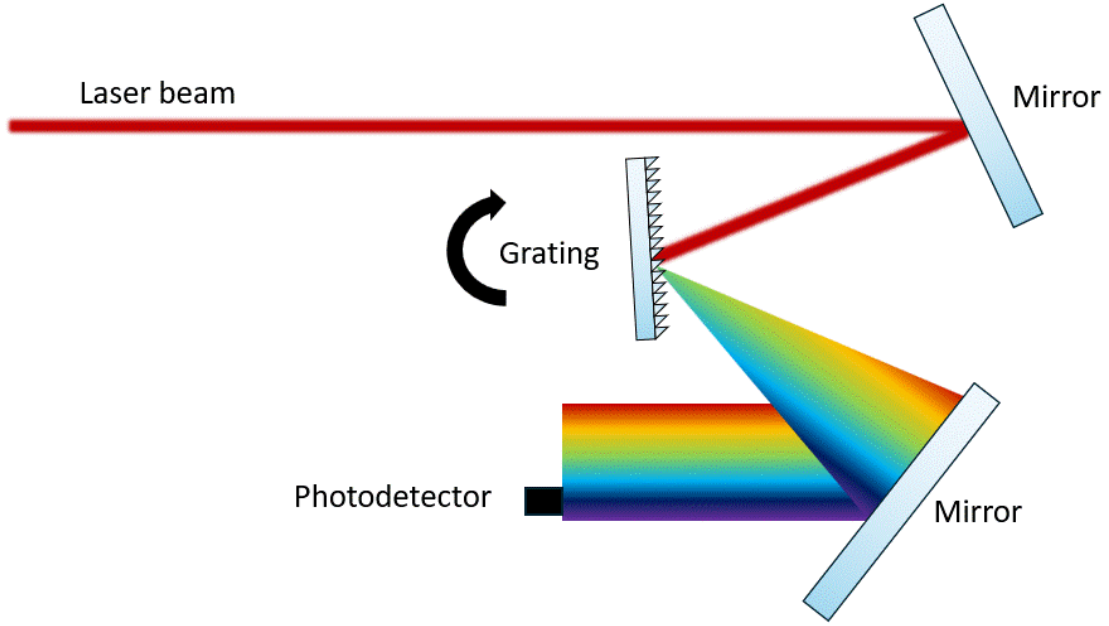


Daylight Solutions

However, fast and multispecies detection in Mid-infrared broadband spectroscopy is challenging.

Detection techniques for Mid-infrared broadband absorption spectroscopy



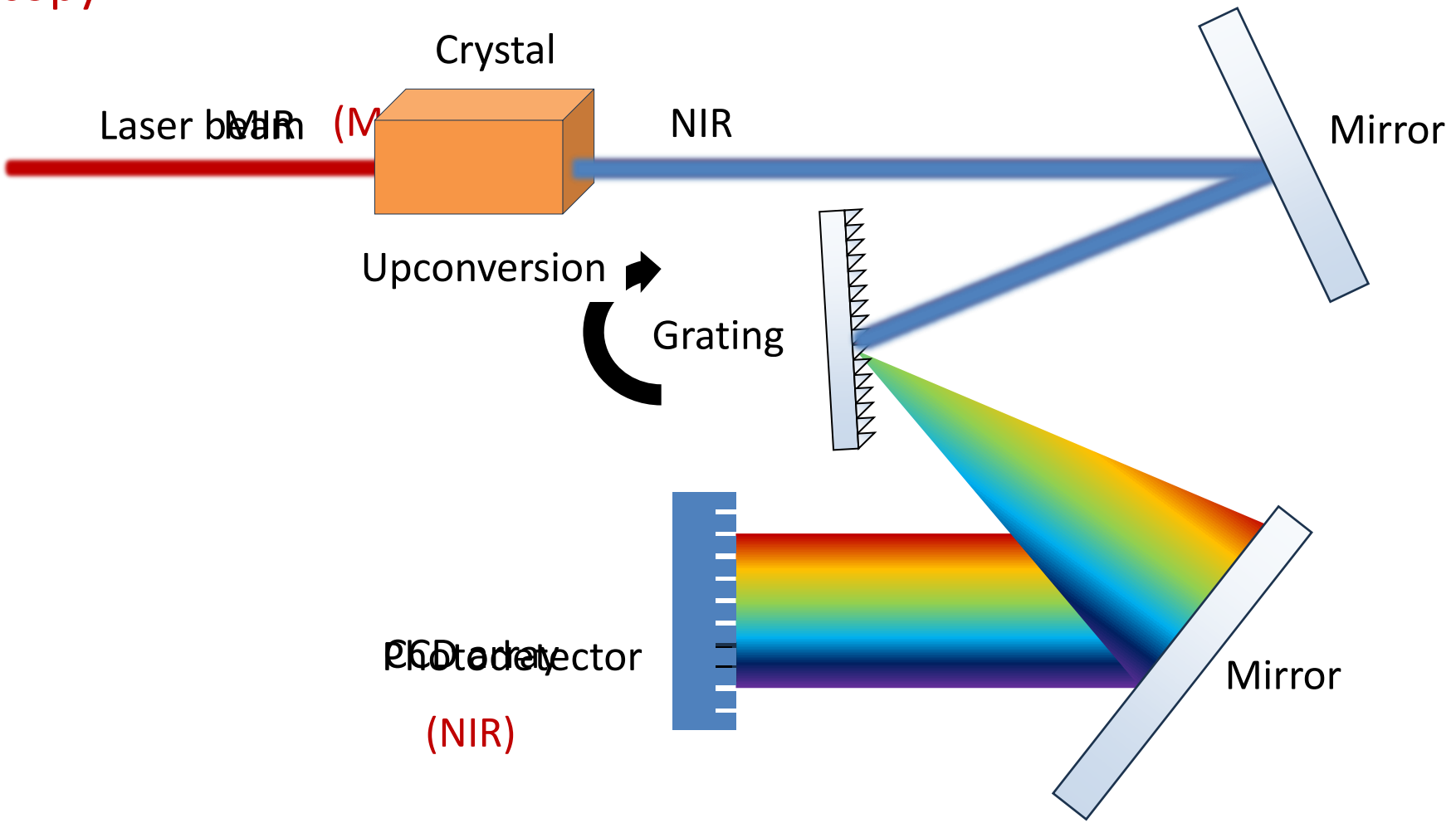


Fourier-transform infrared spectroscopy (FTIR)

Grating spectroscopy (GS)

Detection speed is limited by the mechanical movement.

Solution: Capture the whole spectrum simultaneously by using upconversion spectroscopy



Experimental setup

MIR-to-NIR upconverter

- Convert 2.82 – 4 µm to 773 – 840 nm;
- Time resolution: up to **27 ms (37 Hz);**
- Spectral resolution: 6 cm^{-1}.

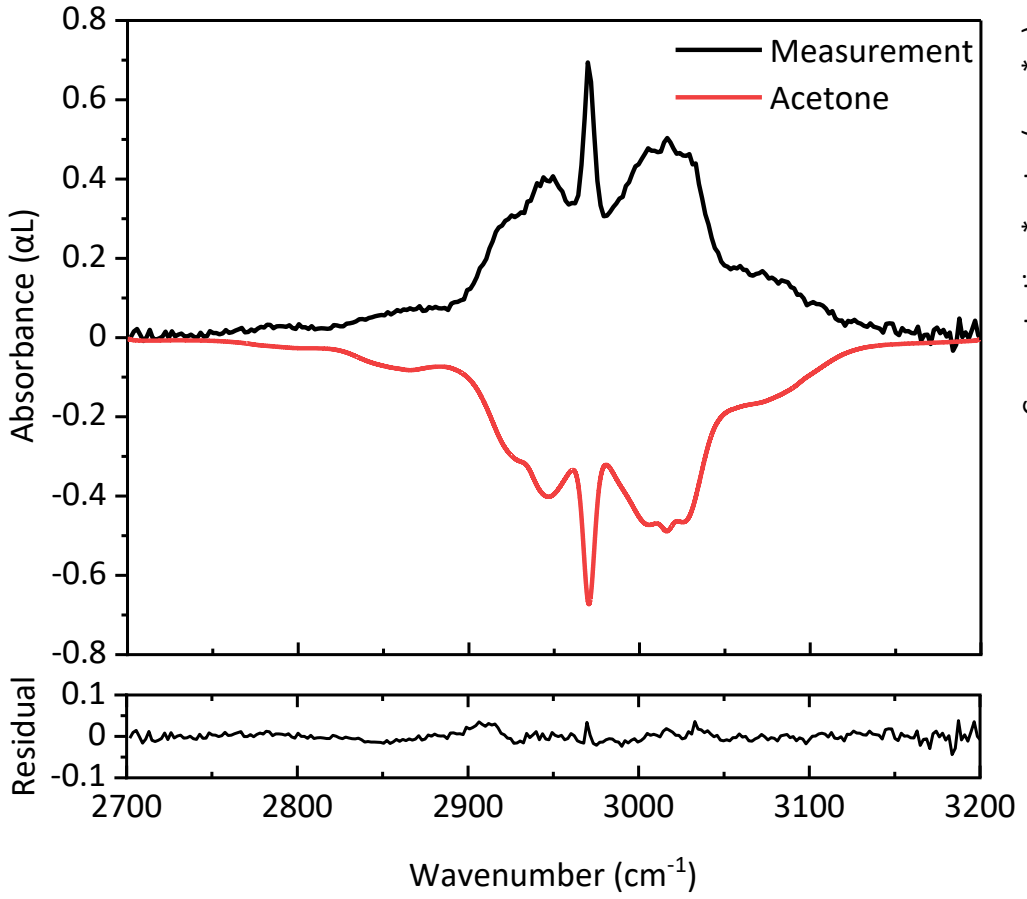
Supercontinuum (SC) source from NKT Photonics, Denmark
450 mW, 1.4 – 4.1 µm

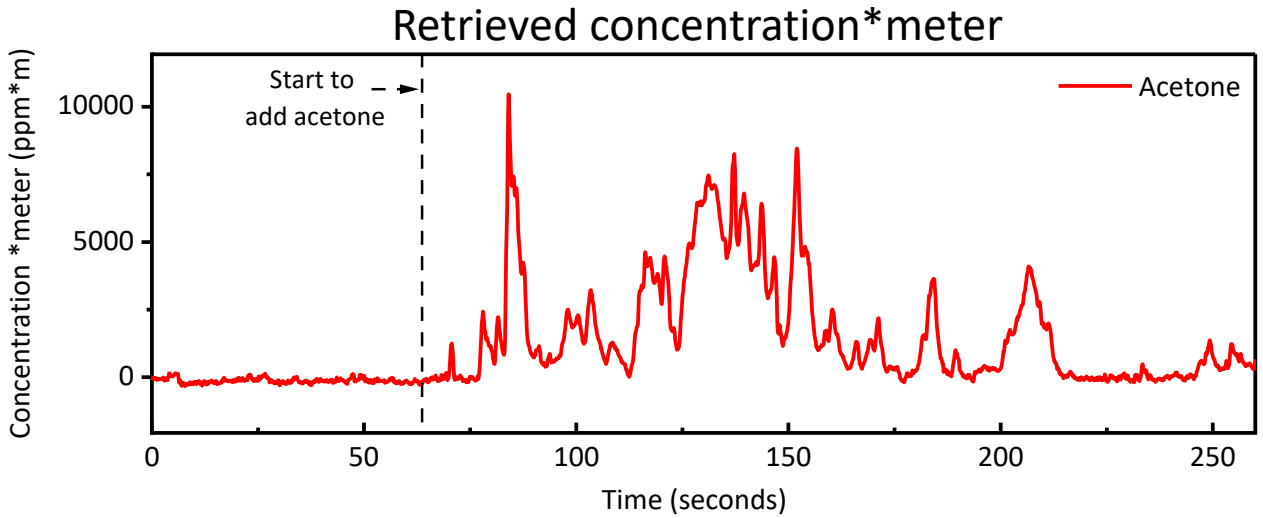
- Broad spectral coverage;
- High optical brightness;
- Spatial coherence.

Liquid evaporation:

- "Open cell": two concave mirrors (40 cm apart, 38.2 m effective path length) .
- Sample: acetone, ethanol, alpha-pinene.

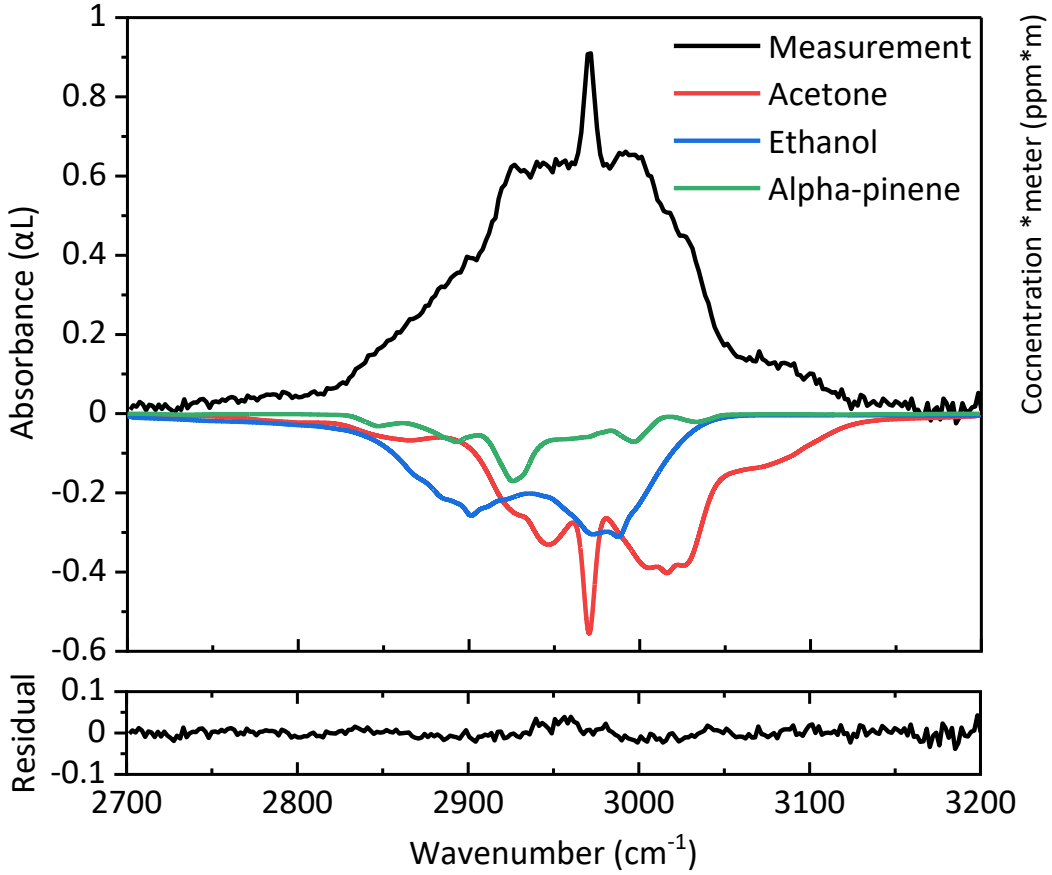
Single spece detection (25 °C): 1 mL acetone (example)

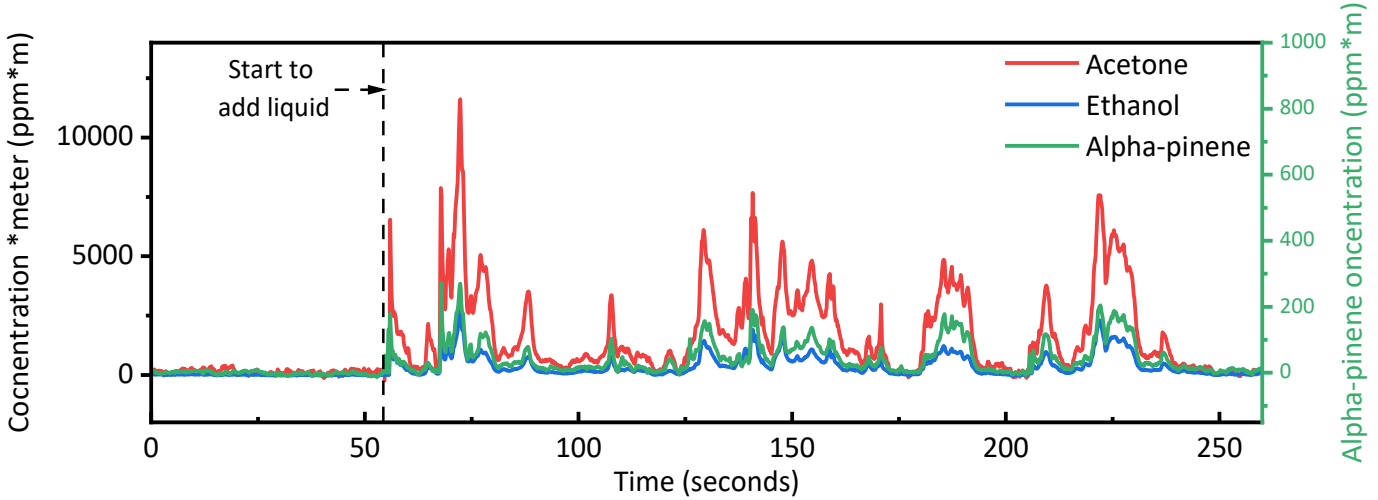




- Spectral coverage: 2700 – 3200 cm^{-1};
- Time resolution: 128 ms per spectrum;
- Fitting with PNNL-based simulated spectrum;

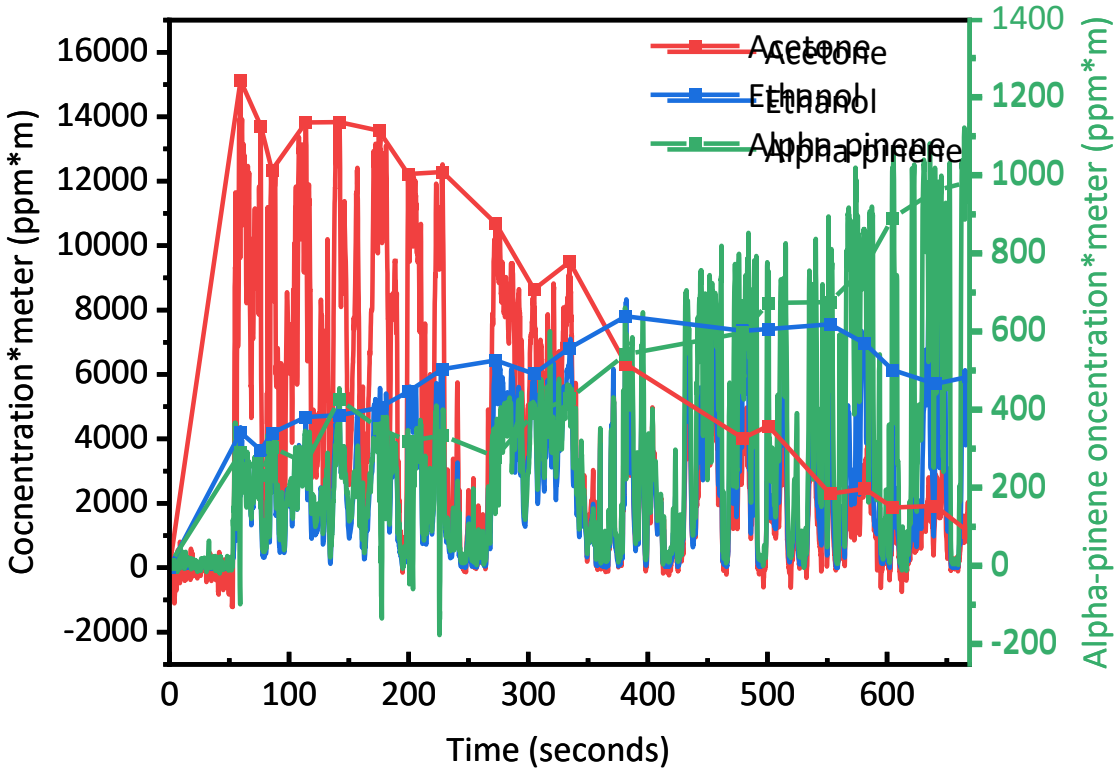
Multi species detection (25 °C): liquid mixture of 1 mL acetone, 0.5 mL ethanol, 2 mL alpha-pinene.





- Fitting with PNNL-based simulated spectra;
- Multi species detection without any interference;

Multi species detection (40 °C): liquid mixture of 1 mL acetone, 0.5 mL ethanol, 2 mL alpha-pinene.



- Simplify the curves by choosing the local peak values;
- Different concentration trends of different species;

Vapor pressure (40°):

- Acetone: ~533 mbar;
- Ethanol: ~173 mbar;
- Alpha-pinene: ~ 14 mbar;

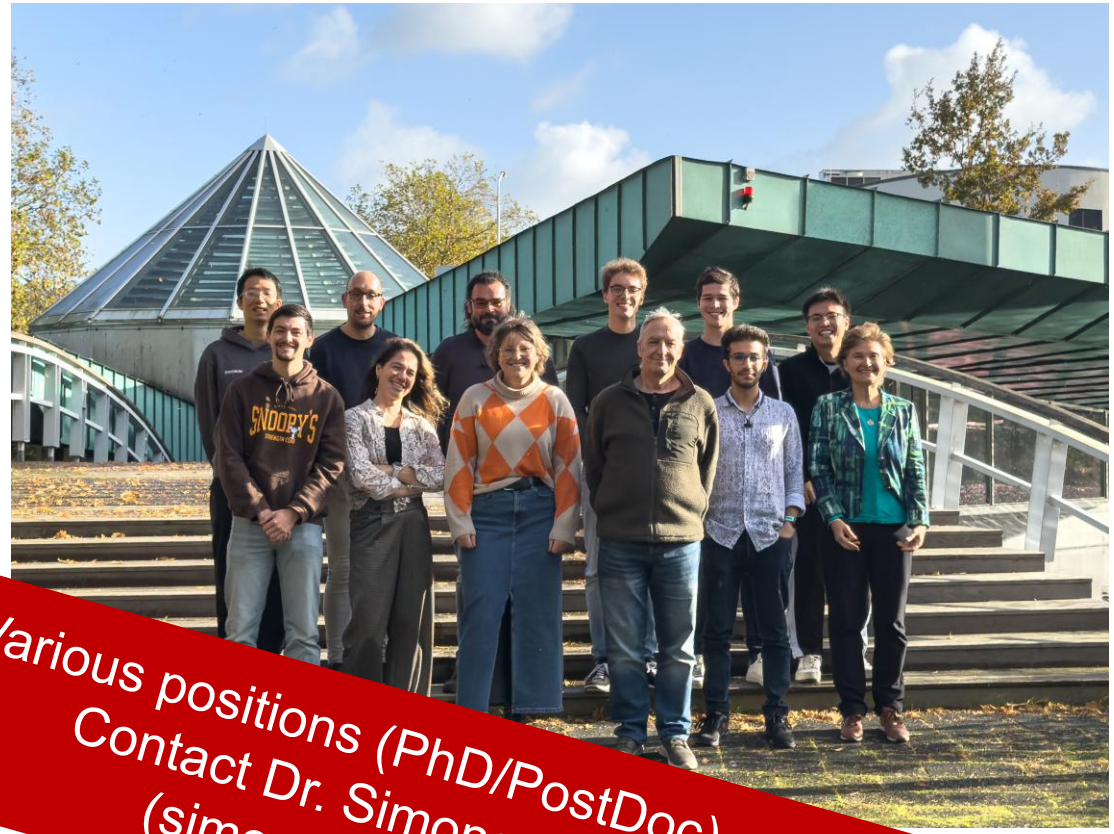
Conclusion:

- A system was developed to achieve fast detection (128 ms/8 Hz) for Mid-infrared broadband spectroscopy;
- Multi-species detection in liquid evaporation;
- Tracing the dynamics of individual compound in the mixture.

Outlook:

- Further optimize the experiment setup for better performance, e.g., higher time resolution;
- Adapt the experimental setup for outdoor applications (e.g., eddy covariance (5 – 40 Hz) in GHG emissions)

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Various positions (PhD/PostDoc) available!
Contact Dr. Simona M. Cristescu
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Prof. Vincenzo Spagnolo

https://tdlab.nl/

Thank you all for your attention !