IRsweep

Innovation in sensing

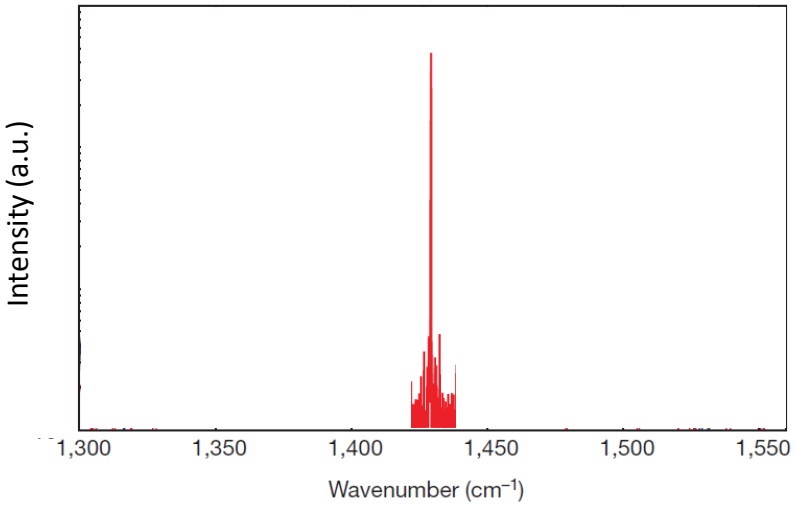
SWISS PHOTONICS

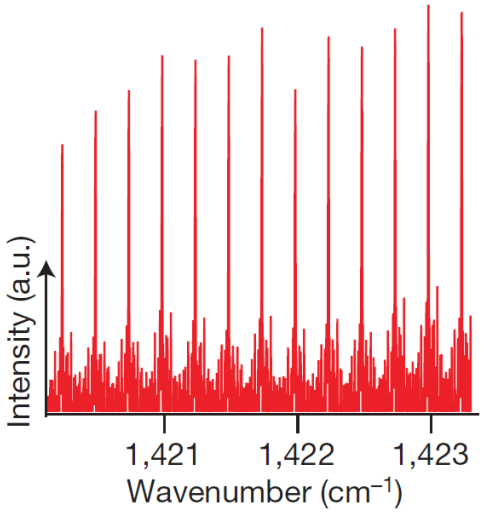
EMPA
Materials Science & Technology

Workshop on optical gas sensing

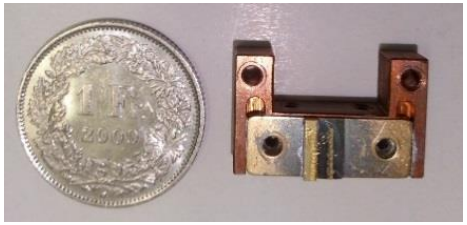
Spinoff ETH zürich

The QCL frequency comb





- A laser emitting many wavelengths at the same time.
- Covering a broad spectral range of tens to a few 100 wavenumbers.
- Spectrum consisting of very sharp, equally spaced lines.

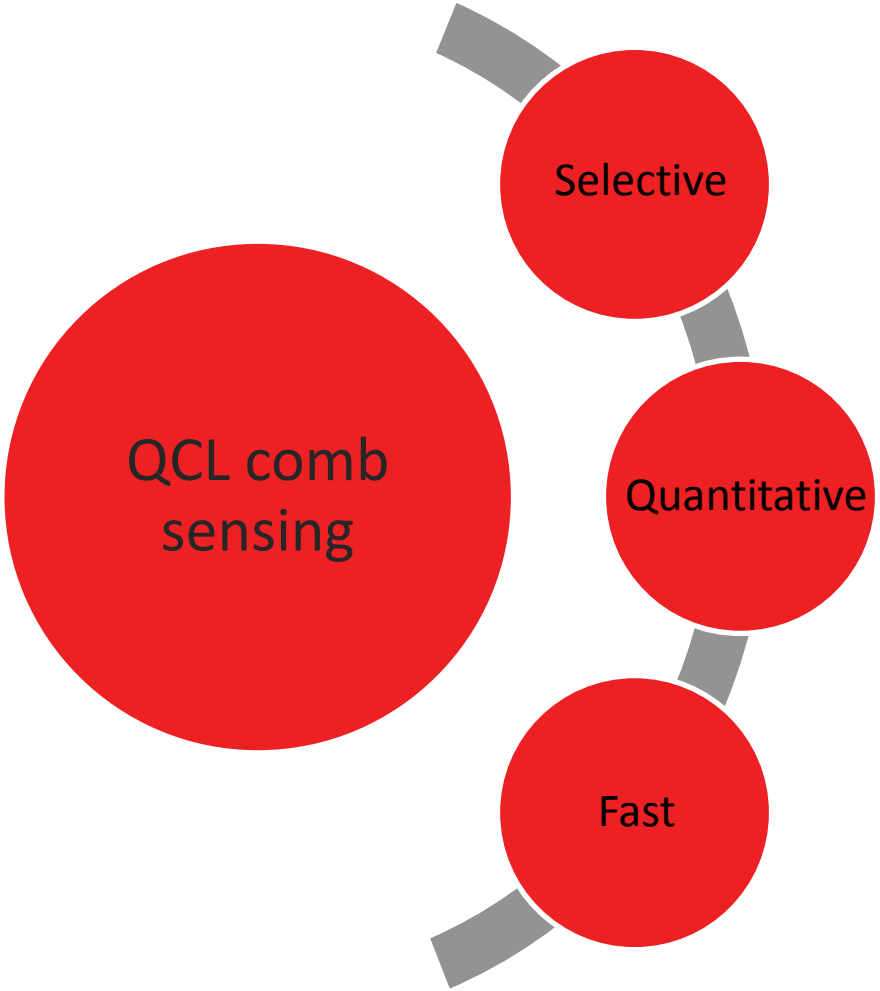


ALPES LASERS

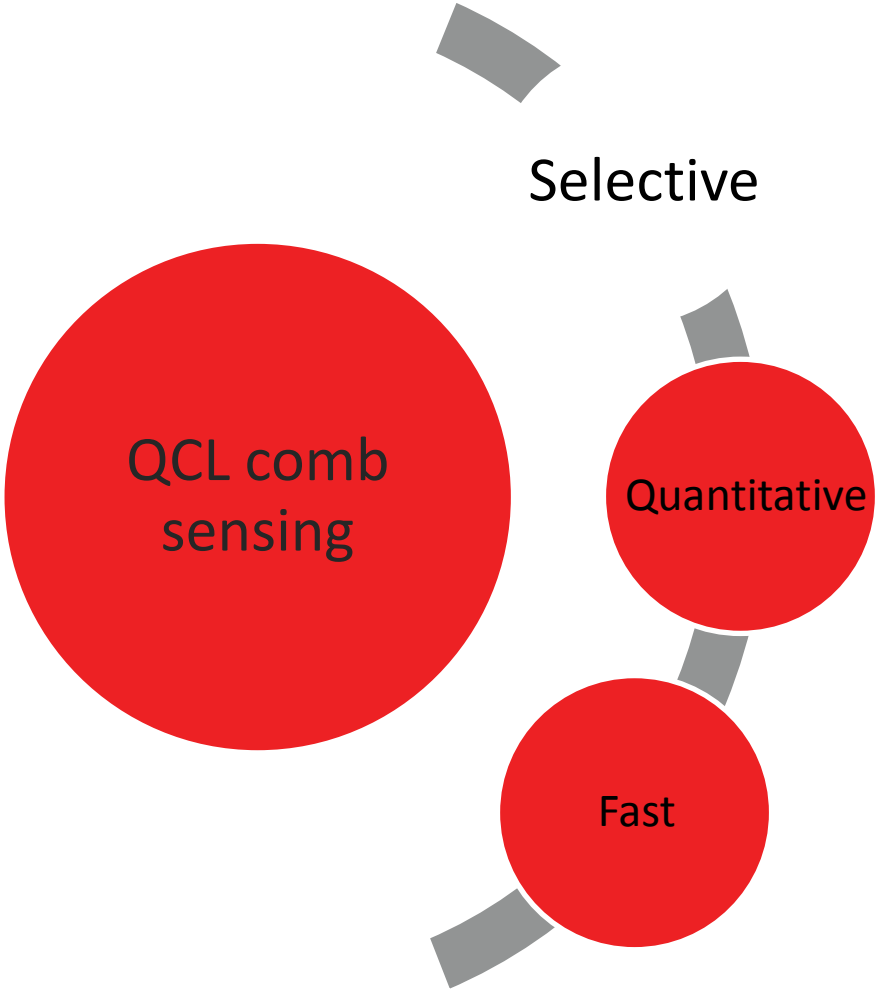
A. Hugi, *et al.*, Nature 492, 229 (2012).

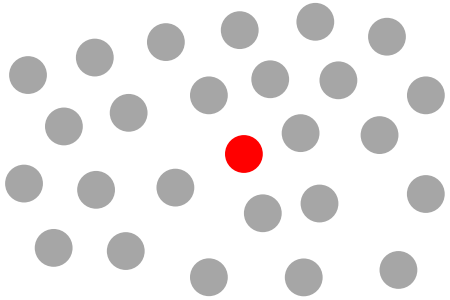
IRsweep

IRsweep optical sensor platform



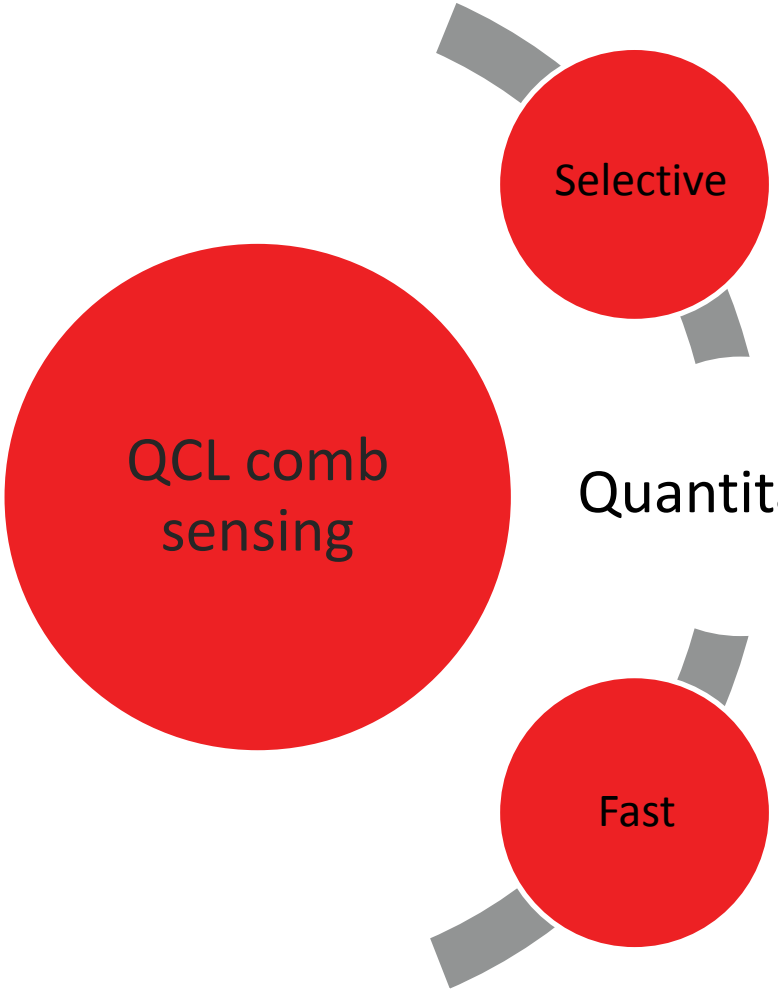
IRsweep optical sensor platform

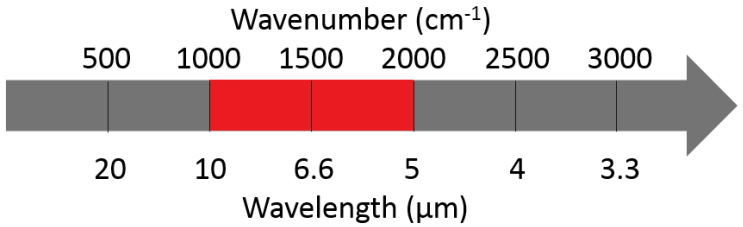




- Hundreds of lasers in one single laser
- High resolution

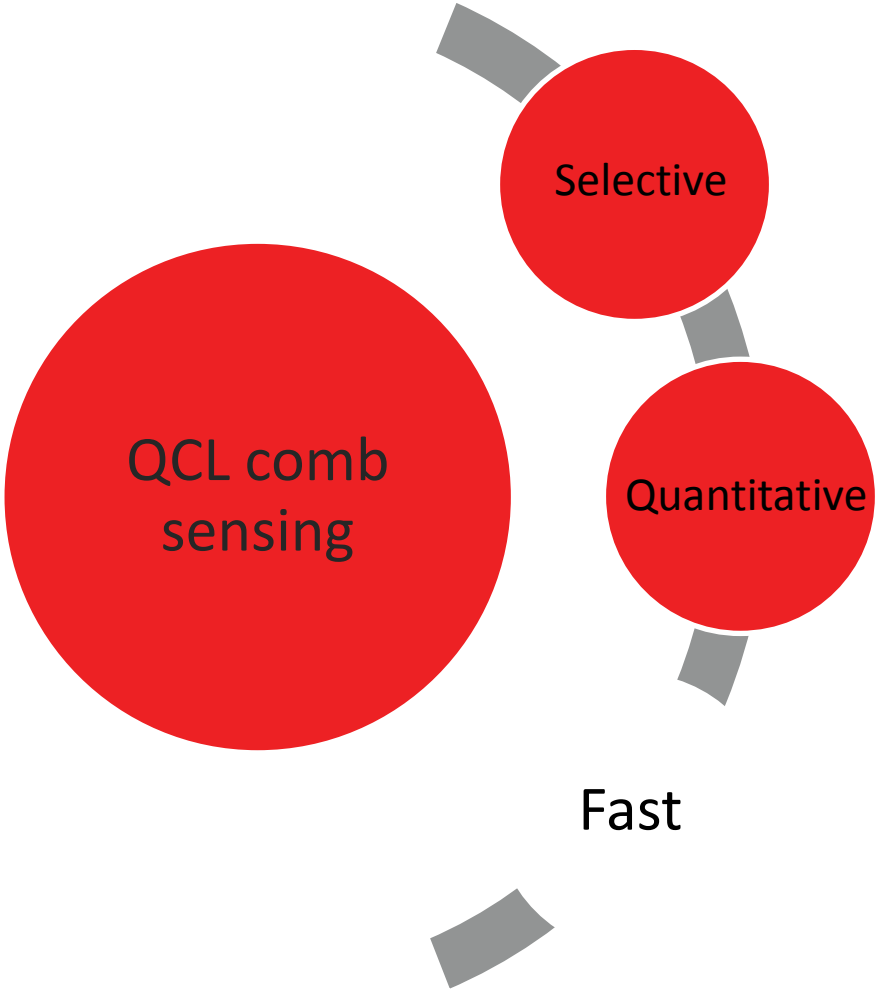
IRsweep optical sensor platform

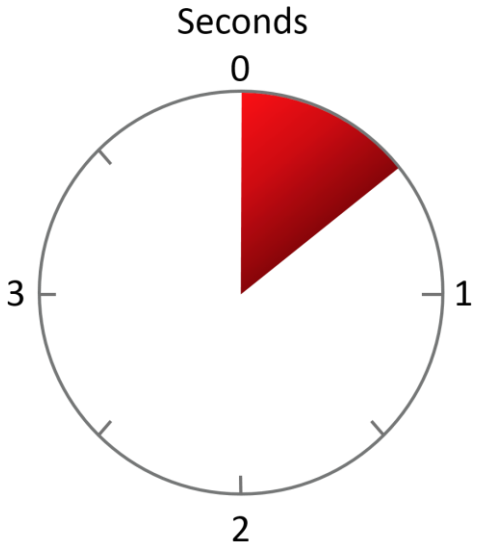




- Mid-infrared range: Sweet spot for sensing
- Laser based system
- Sensitivity: ppm, ppb

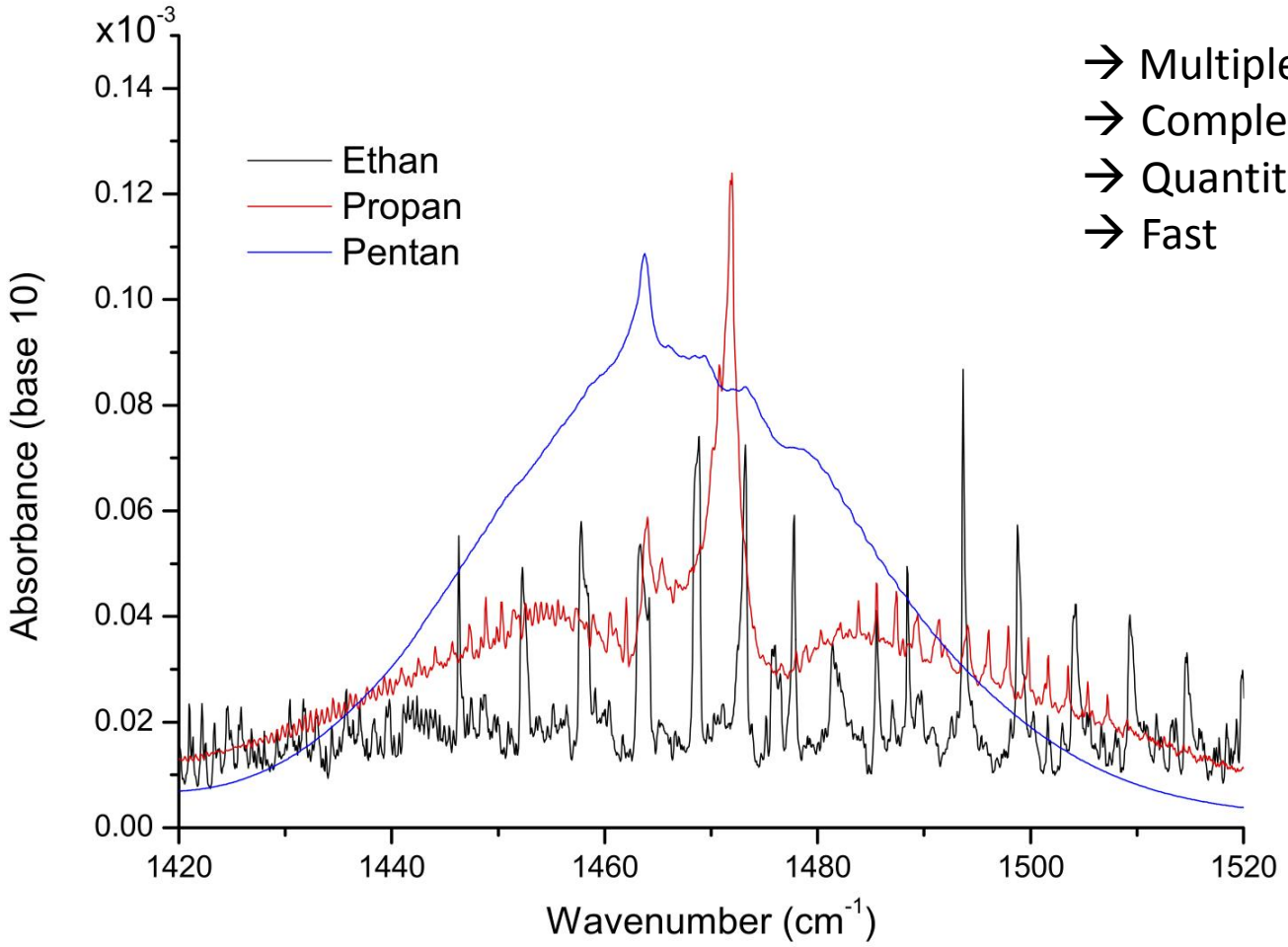
IRsweep optical sensor platform





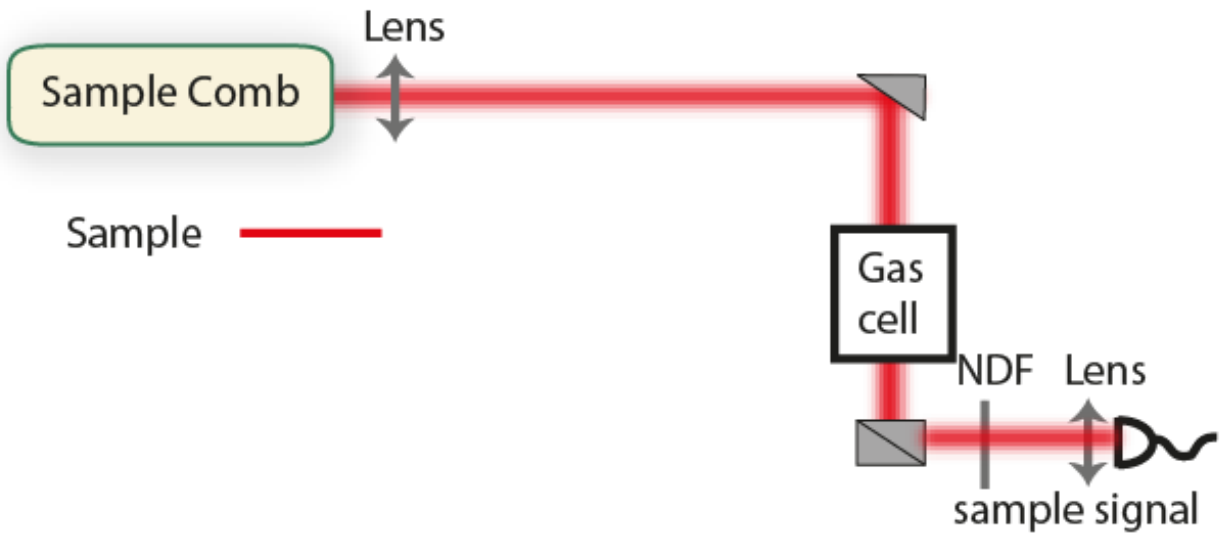
- **100 µs** to get entire information (spectrum)

Example exploiting these features



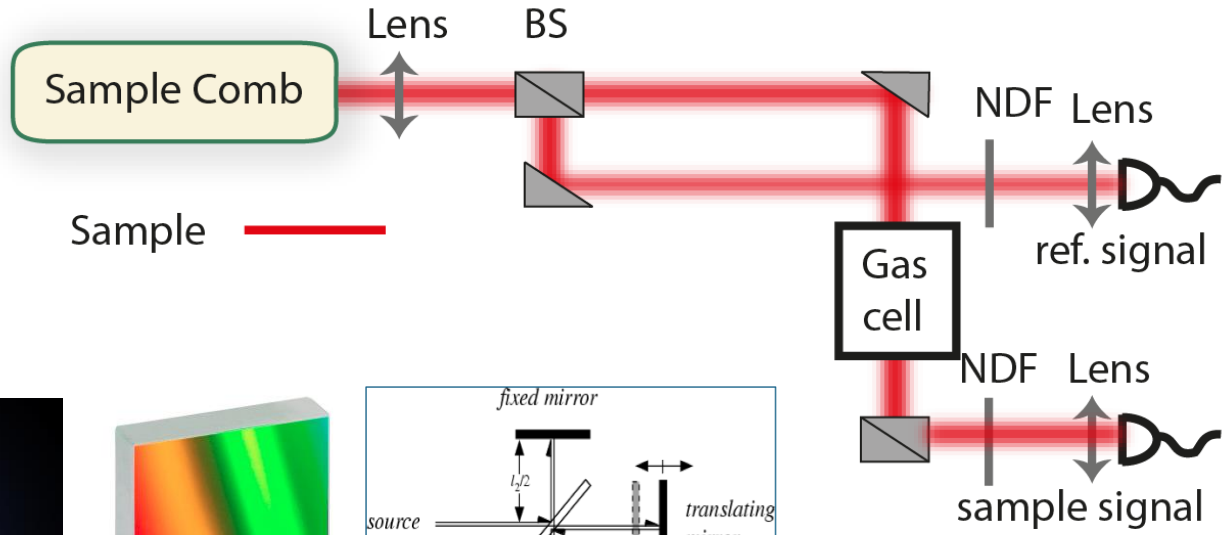
→ Multiple molecules
→ Complex background
→ Quantitative
→ Fast

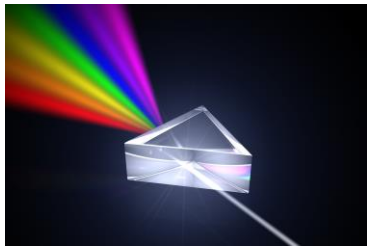
Dual comb spectroscopy



Villares et al., “Dual-comb spectroscopy based on quantum-cascade-laser frequency combs”, Nature Comm. 5, Art. 5192, Oct. 2014.

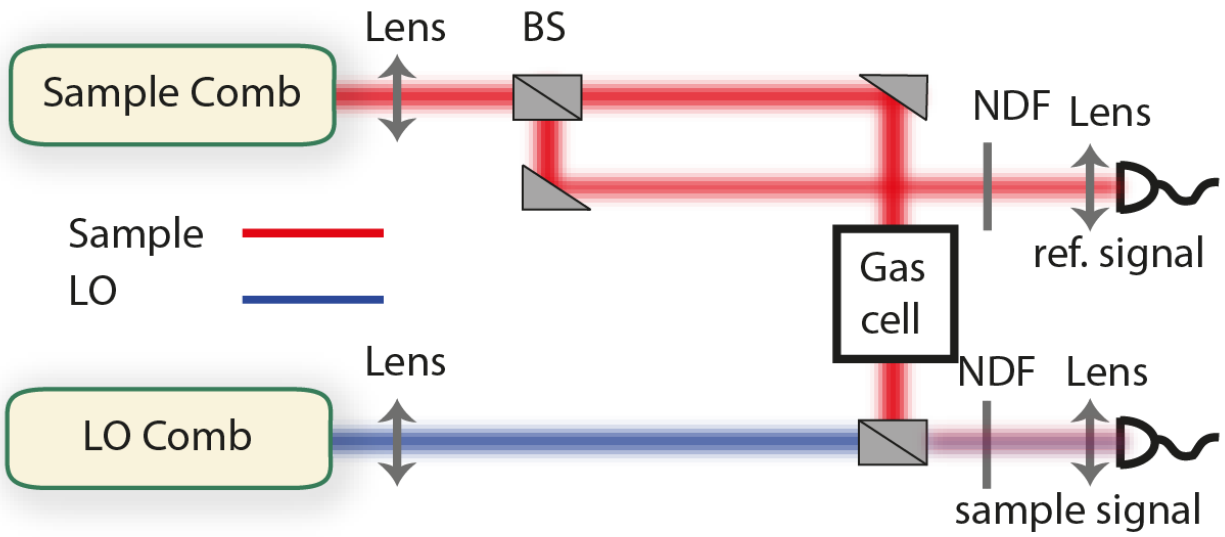
Dual comb spectroscopy





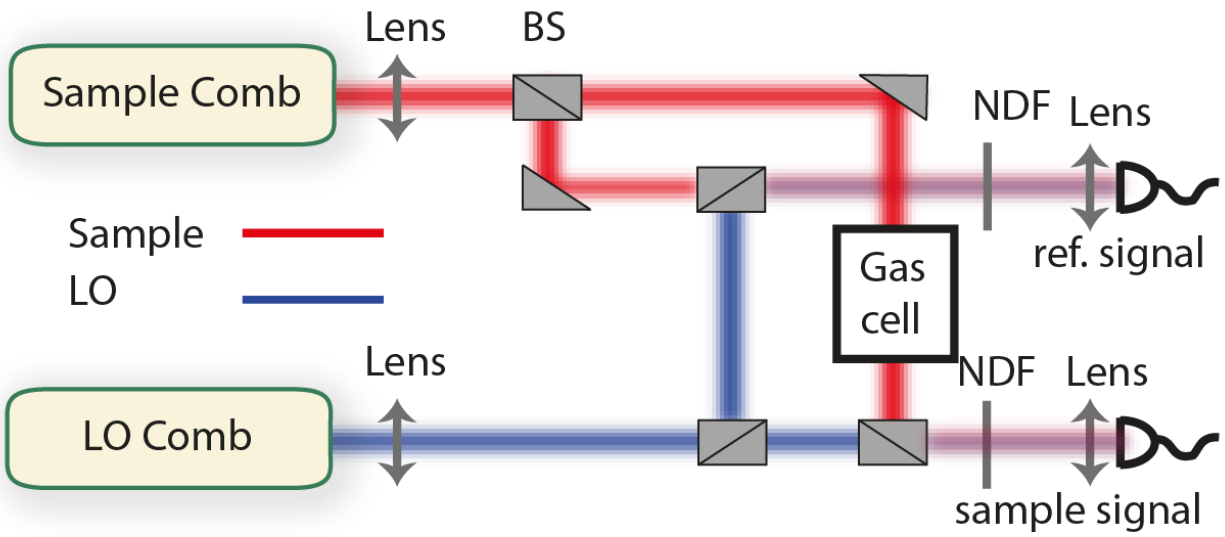
Villares et al., "Dual-comb spectroscopy based on quantum-cascade-laser frequency combs", Nature Comm. 5, Art. 5192, Oct. 2014.

Dual comb spectroscopy



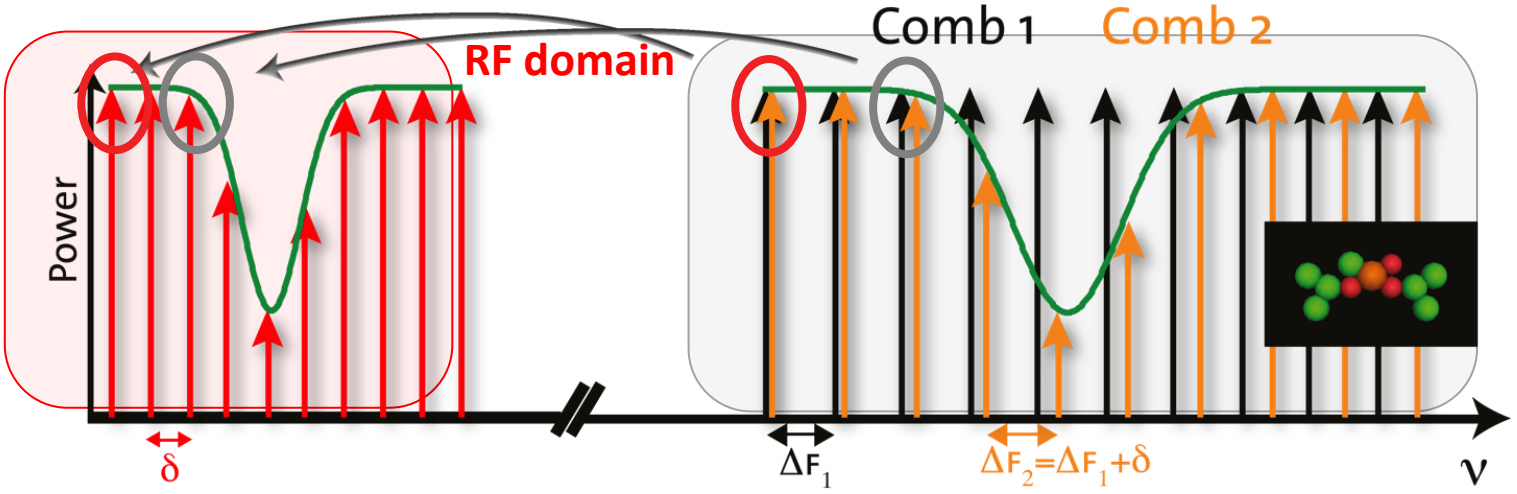
Villares et al., "Dual-comb spectroscopy based on quantum-cascade-laser frequency combs", Nature Comm. 5, Art. 5192, Oct. 2014.

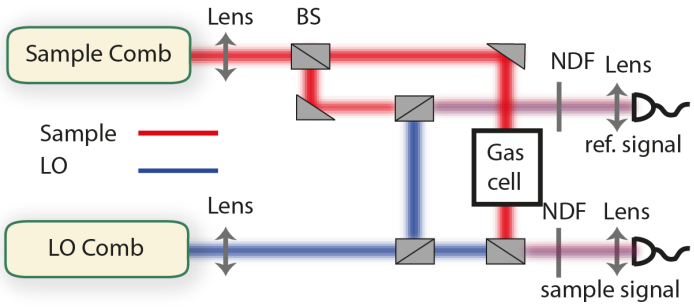
Dual comb spectroscopy



Villares et al., "Dual-comb spectroscopy based on quantum-cascade-laser frequency combs", Nature Comm. 5, Art. 5192, Oct. 2014.

Dual comb spectroscopy





No moving parts, very fast!

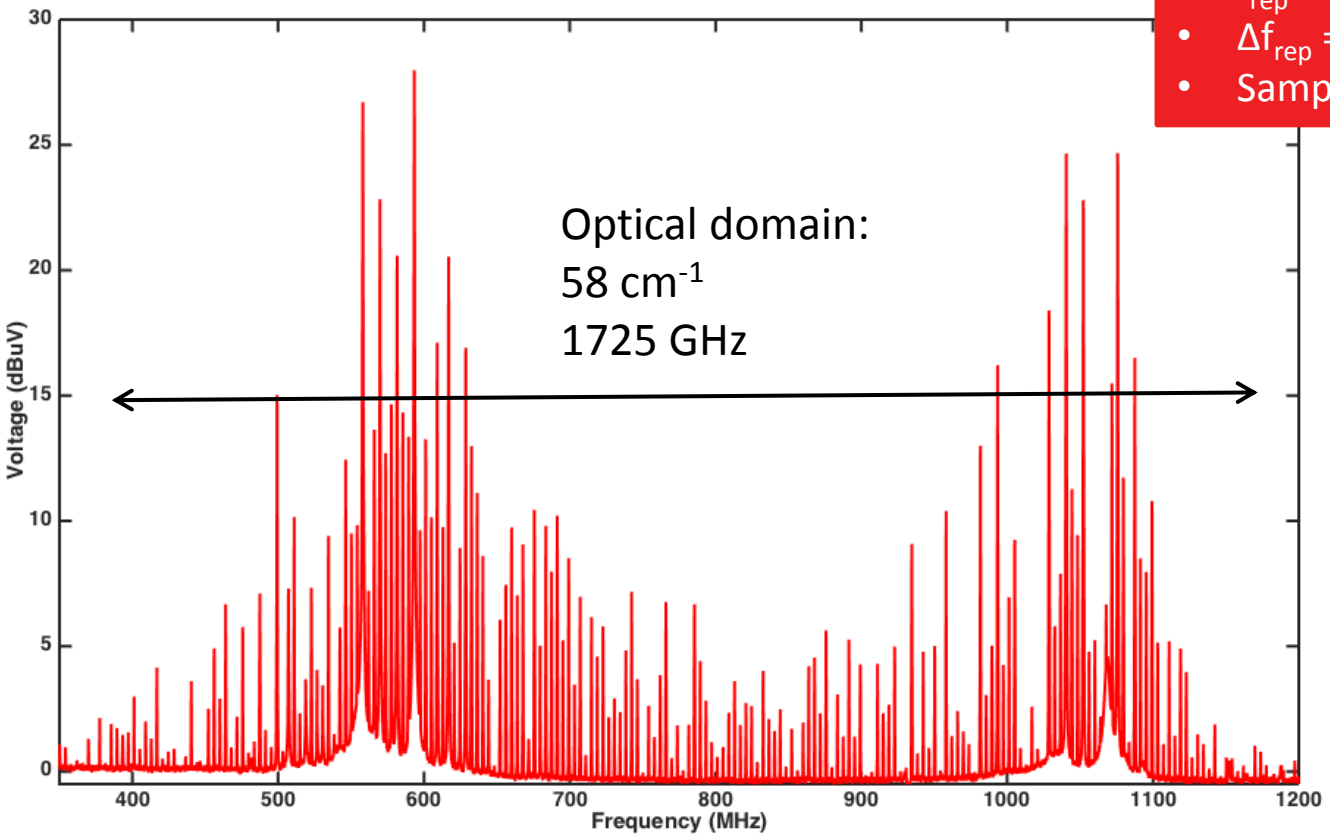
Characteristics:

- Comb bandwidth → spectral coverage
- Comb repetition freq. → sampled absorption
- Linewidth of a comb line → resolution

IRsweep

Multi-heterodyne measurement

Important numbers:
- Lines = 230;
- f_{rep} = 7.5 GHz
- Δf_{rep} = 3.5 MHz
- Sampling = 0.25 cm^{-1}

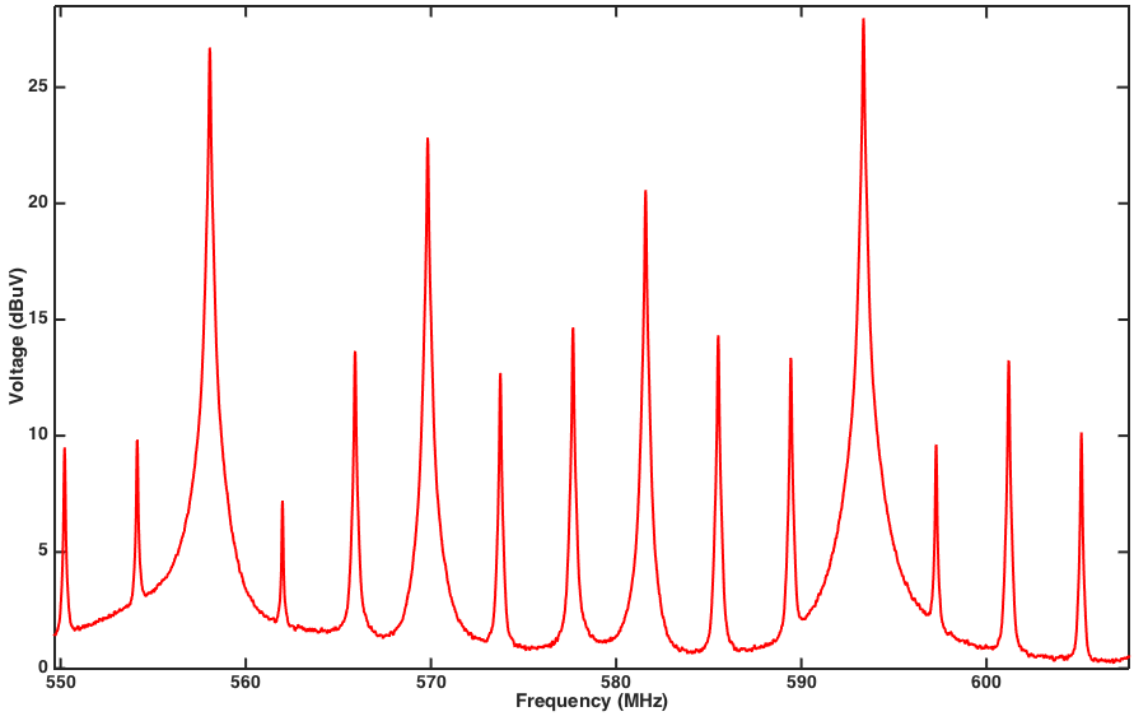


30 conventional single mode DFB lasers

Spectral coverage improvement

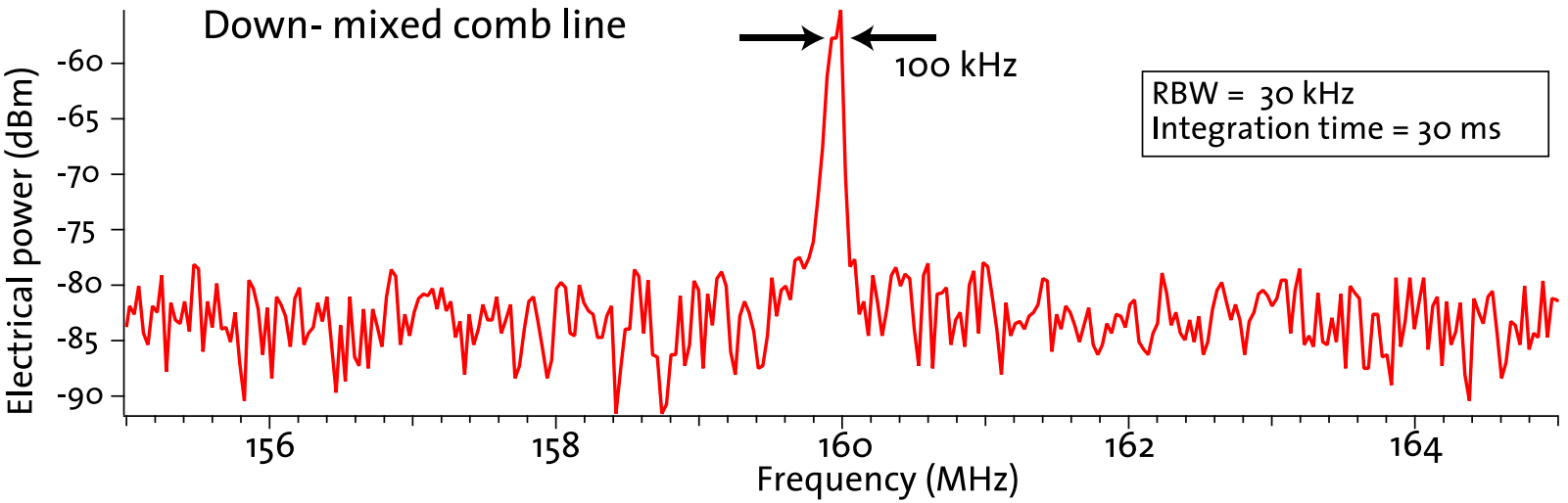
Important numbers:

- Lines = 230;
- f_{rep} = 7.5 GHz
- Δf_{rep} = 3.5 MHz
- Sampling = 0.25 cm^{-1}



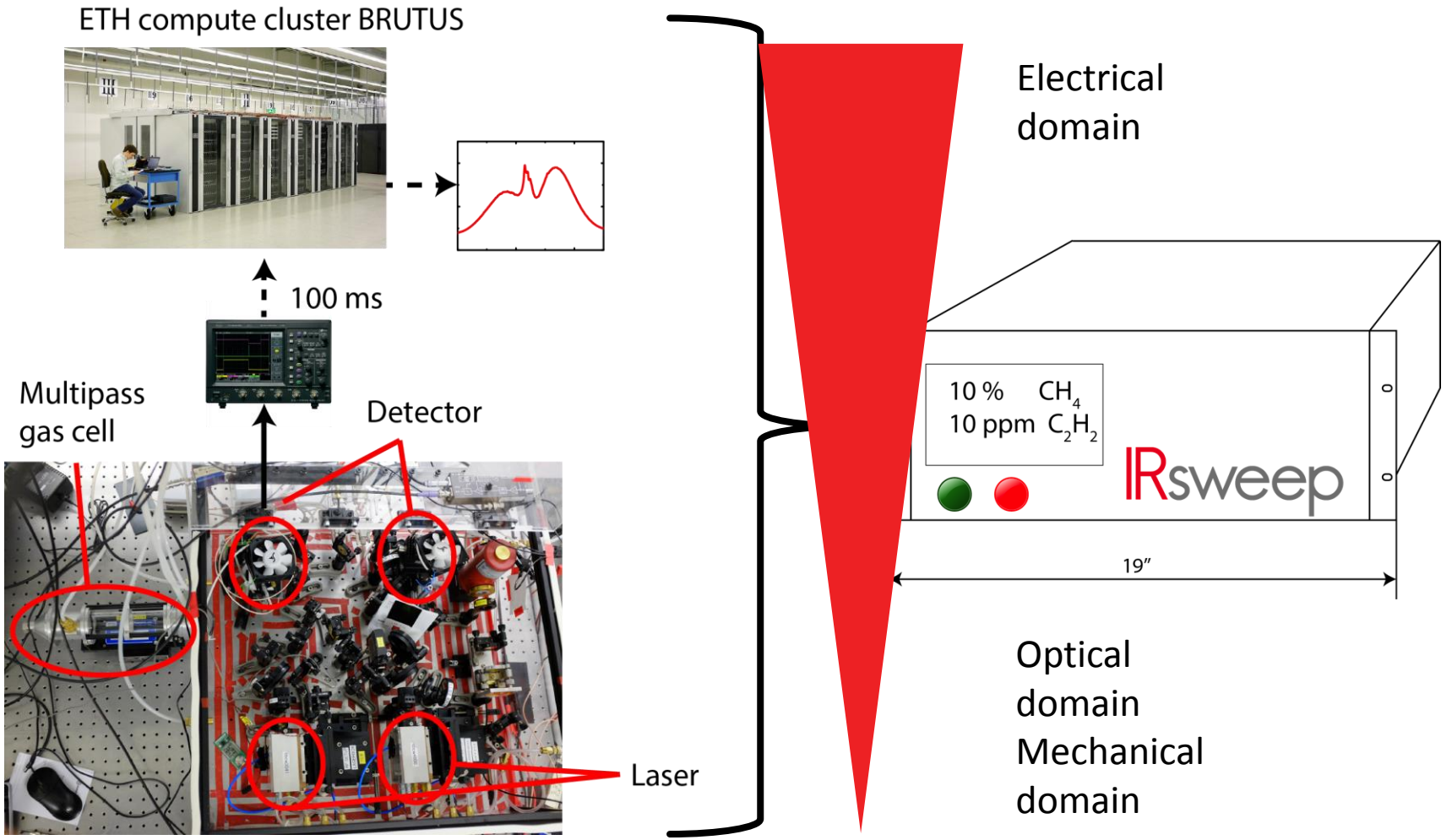
IRsweep

Resolution

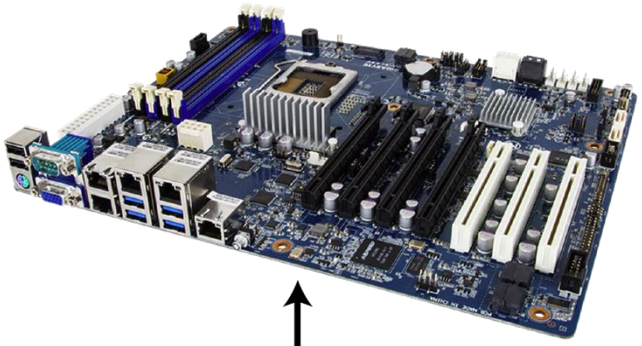


Longer integration times 1-10 MHz resolution.

Dual comb laser system challenges



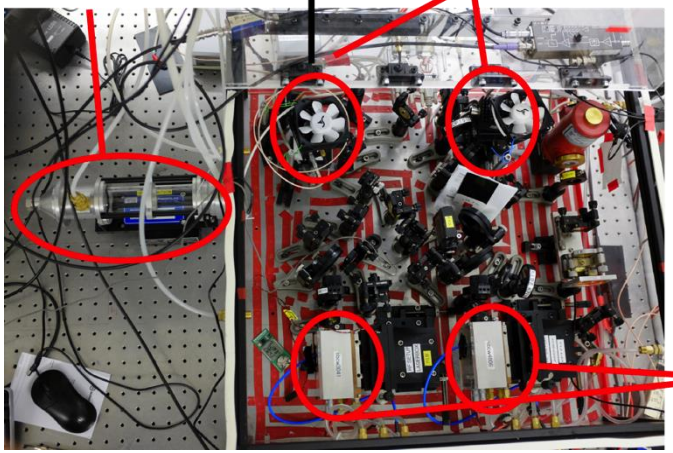
Broadband laser system challenges



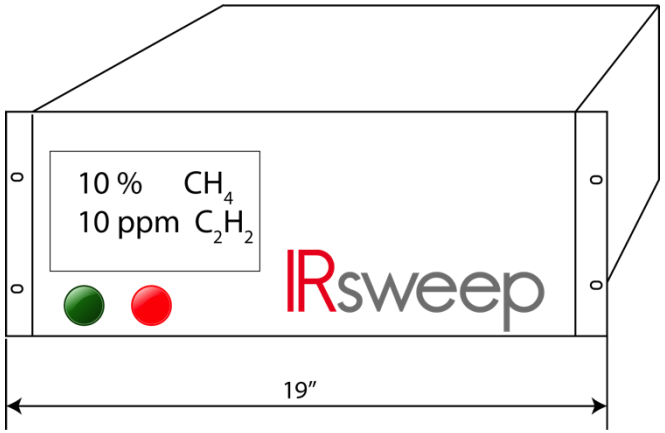
Infinite integration time

Multipass gas cell

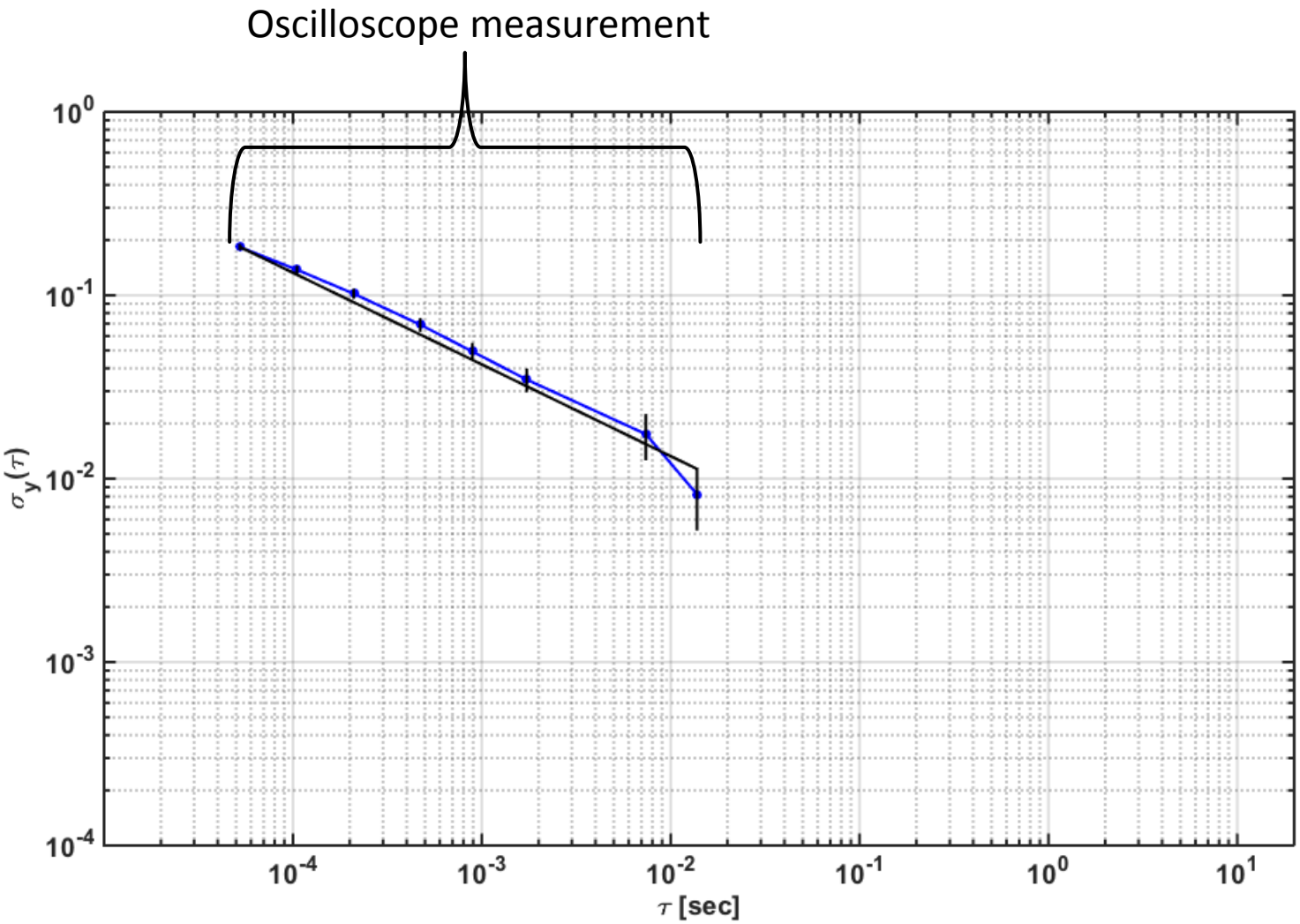
Detector



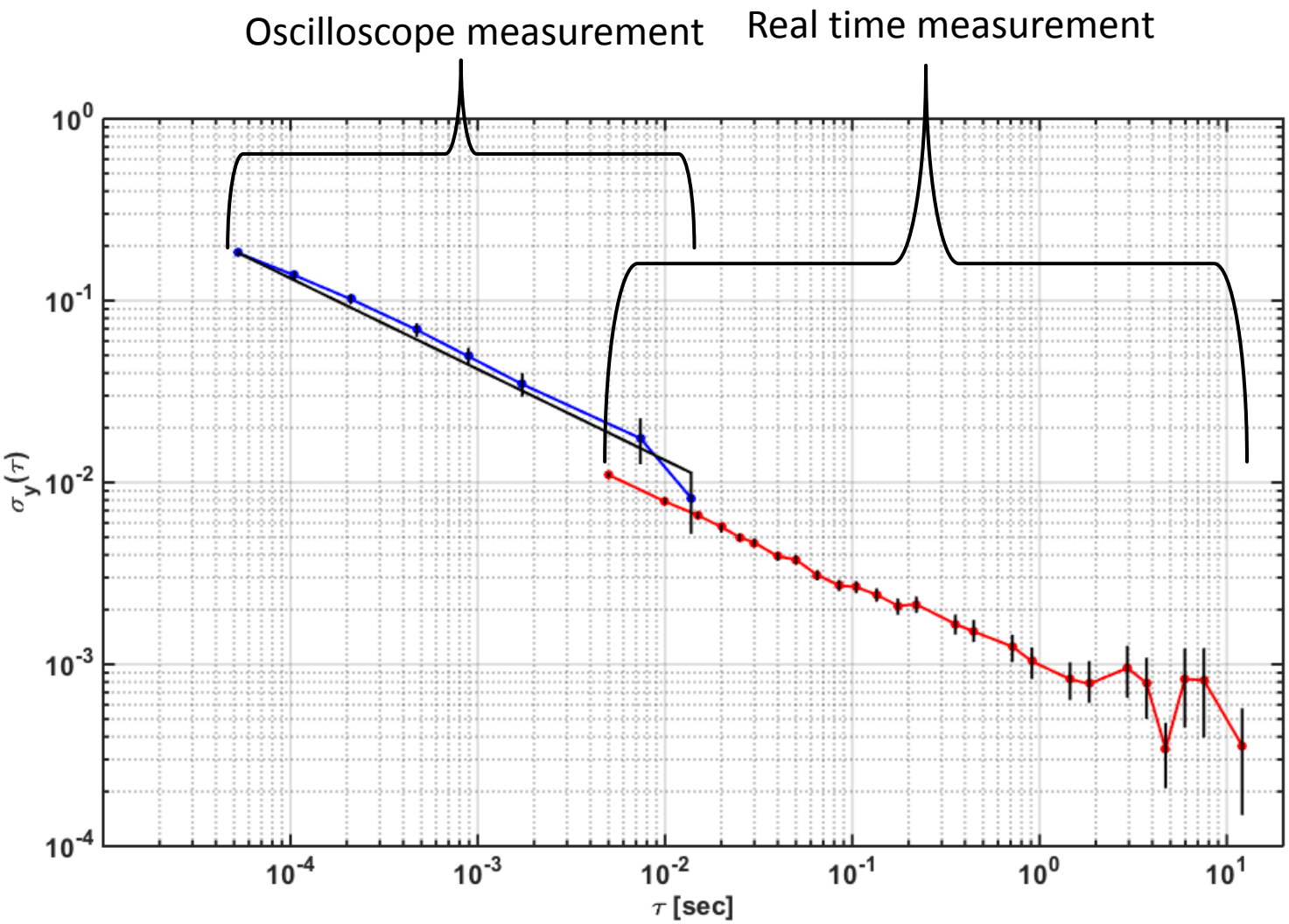
Laser



Allan deviation

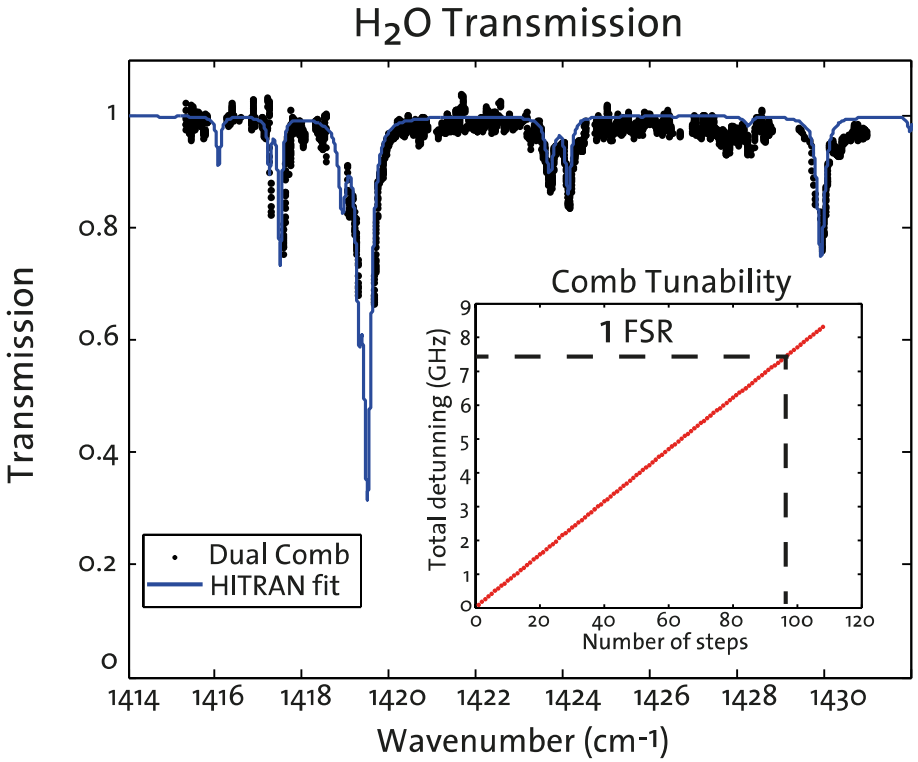


Allan deviation



What we already measured – Technology demonstrator in the lab

- The spectroscopy system is operational on a lab level.
  The water vapor absorption spectrum below was acquired in 40 milliseconds.



Thanks

- Jérôme Faist and his group
  - Gustavo Villares
  - Francesco Cappelli
- Lukas Emmenegger
- ETH Zürich – Pioneer Fellowship program
  - Peter Seitz
  - Alexander Stuck
- Alpes Lasers
- Others:

ETH zürich

EMPA
Materials Science & Technology

VENTURE KICK

KTI/CTI
DIE FÖRDERAGENTUR FÜR INNOVATION
THE INNOVATION PROMOTION AGENCY

IRsweep

Contact us: info@irsweep.com

We are taking QCL comb sensing technology to the market.

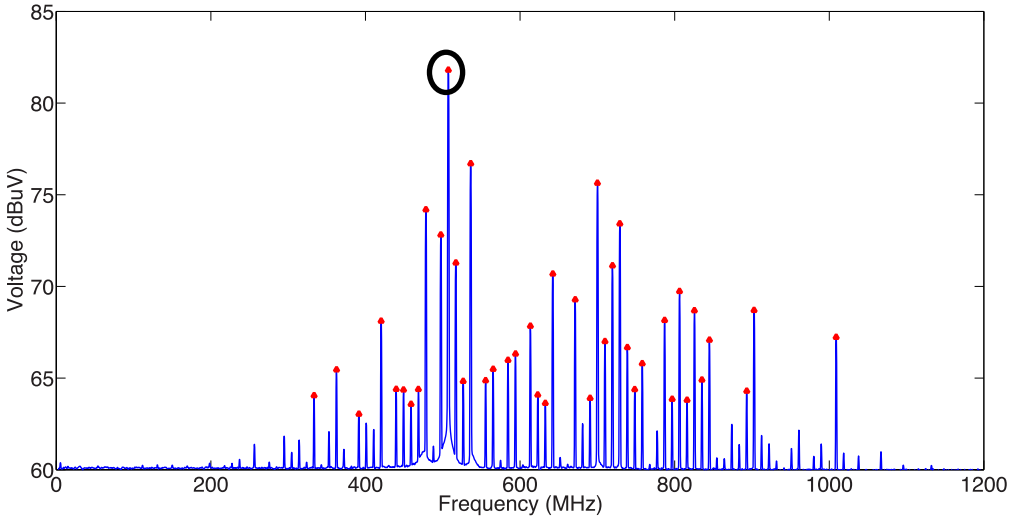
Questions?

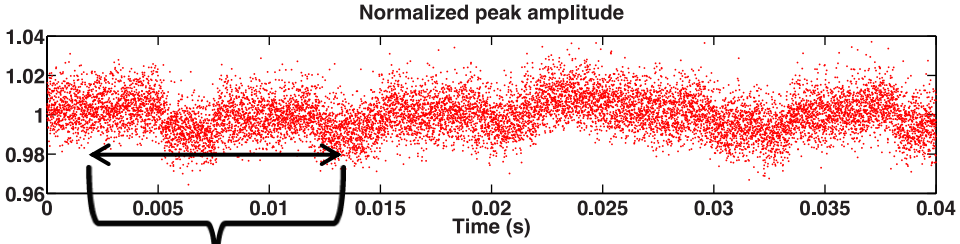
Dr. Andreas Hugi (ETH)
Dr. Markus Geiser (ETH)
Dr. Markus Mangold (EMPA)

Spinoff ETH zürich

IRsweep

Allan deviation of peak amplitude





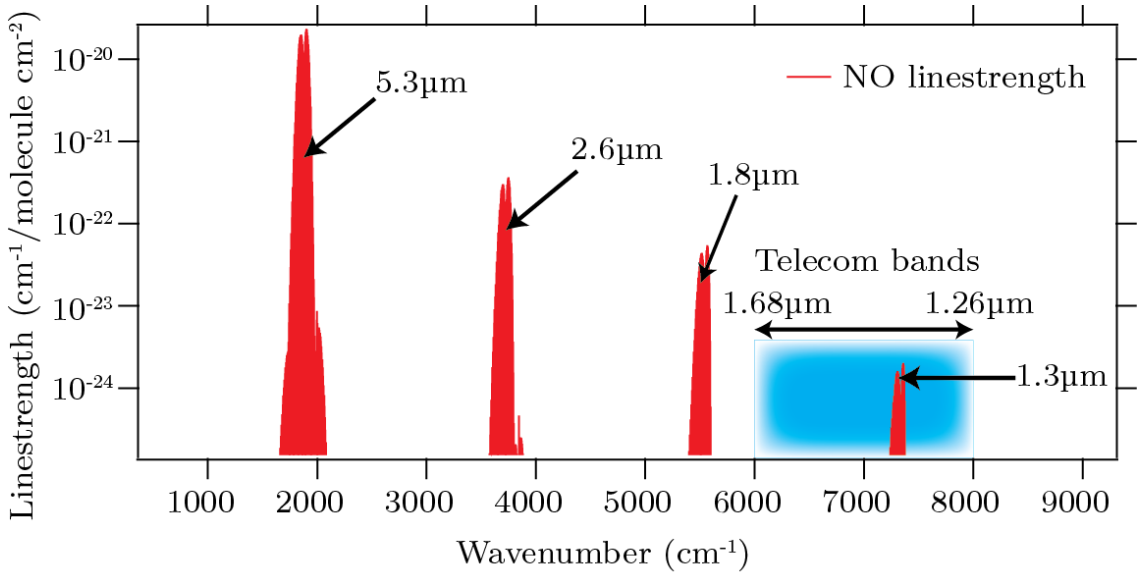
$$\bar{y}_k = \frac{1}{\tau}\int_{t_k}^{t_k+\tau} y(t)\,dt$$

-> Set spectrometer sensitivity

Allan variance:

$$\sigma_{\mathrm{A}}^2(\tau) \equiv \left\langle \frac{1}{2}(\bar{y}_{k+1} - \bar{y}_k)^2 \right\rangle$$

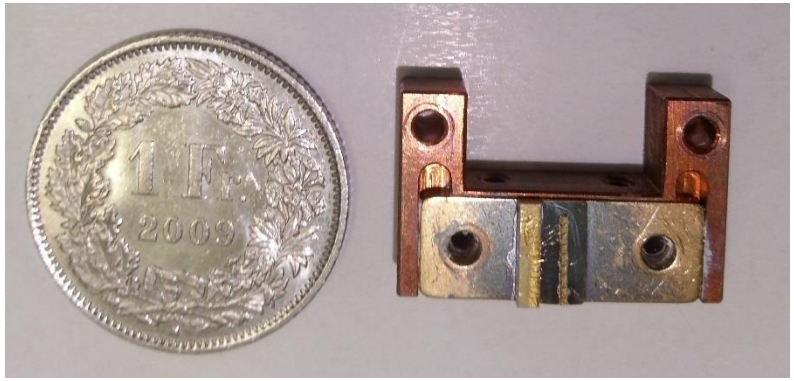
Mid infrared vs. near infrared



	MIR	NIR
Selectivity	++	O (Combination bands)
Sensitivity	++	O (Trade off with selectivity)
Price	-	+

Dual comb spectroscopy mid infrared vs. near infrared

- Comb source required for
  - aequidistance of modes
  - stability



IRsweep solution

- NIR comb sources are:
  - optically pumped
  - challenging to fabricate & operate