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The spatial heterogeneity effects on dTDLAS-based CO sensor for industrial emission monitoring applications

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Introduction & Motivation

Accurate measurement of emissions of pollutants to the atmosphere is vital in enabling action to control and reduce air pollution. Industry needs to measure and report emissions for regulatory purposes including assessing stack emissions against concentration limit values.

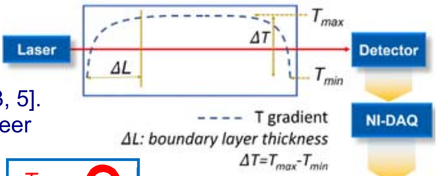
The EMPIR IMPRESS 1 and IMPRESS 2 projects [1] go beyond state of the art in measuring the emissions of critical pollutants with lower emission limit values, to achieve directly traceable measurements. We present the spatial heterogeneity effects on direct TDLAS (dTDLAS) method for absolute gas concentration measurement.

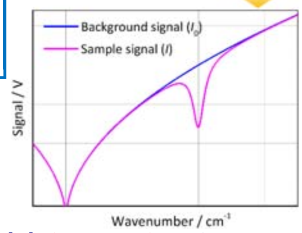
dTDLAS measurement approach

dTDLAS is a first principle approach to directly get absolute gas concentration without any calibration [2, 3, 5]. Amount fraction from the Beer Lambert law:

$$x = \frac{A \cdot k_B \cdot T}{S_T \cdot p \cdot l}$$

T_{max}
T_{min} ?
averaged





Quantities:

A	Line area [cm^{-1}]
k_B	Boltzmann constant
T	gas temperature [K]
L	optical path length [m]
p	gas pressure [Pa]
S_T	line strength of the probed molecular transition at T

Which temperature to use for concentration and line strength calculation?

Heterogeneity effects on dTDLAS

Line-of-sight (path averaged) ➡ **dTDLAS**

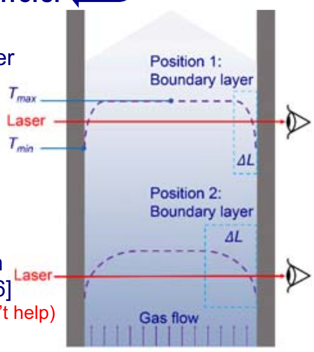
Heterogeneous conditions (e.g. temperature gradient along the path)

Systematic errors!

Example:
TDLAS analyser (**cross-stack**)

T gradient

Concentration deviations [4,6]
(calibration doesn't help)



The deviations should be quantified, especially for **metrologically traceable measurements**.

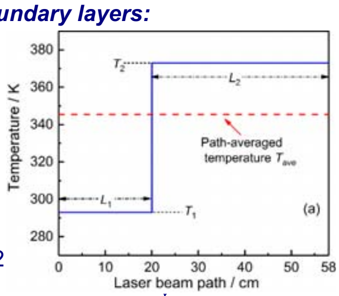
Case study: two-stage T profile

Thermal boundary layers:

- cold: L_1, T_1
- hot: L_2, T_2
- ratio: $\Gamma = L_1/L_2$

T_{max}: T_2
T_{min} : T_1

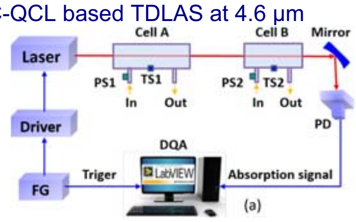
Mean T_m:
$T_m = (T_1+T_2)/2$



Path-averaged T_{ave}: $T_{ave} = \int_0^L T_i \mathrm{d}L_i / L$

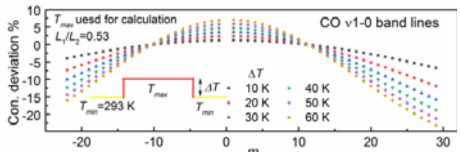
Spectrometer info:

- EC-QCL based TDLAS at 4.6 µm

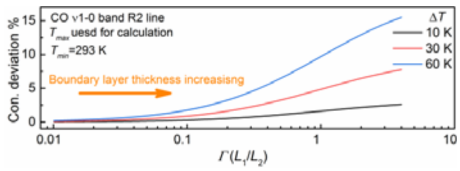


Simulation results for CO lines

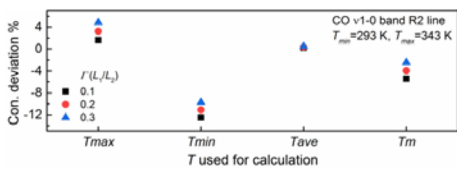
Simulation A: different lines



Simulation B:* Varying pathlength ratio *Γ

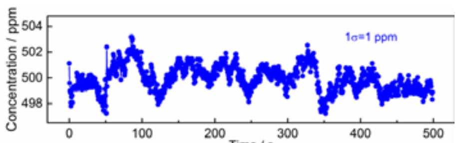


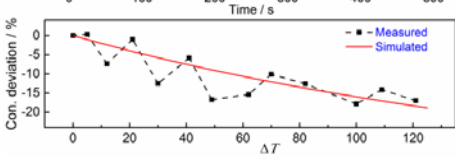
Simulation C:* different calculation *T



Measurement results

- One gas cell was heated
- Test gas: 500 ppm CO in air





Conclusions and outlook

Results:

- Temperature gradient effects was investigated for CO v1-0 band
- Heterogeneity effects can be quantified by simulation
- Systematic errors (deviations) are:
  - Line dependent
  - boundary layer dependent
  - calculation temperature dependent

Plans:

- Heterogeneity effects on HCl line
- Heterogeneity effects on WMS

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