Optical absorption spectroscopy for gas analysis in biomass gasification

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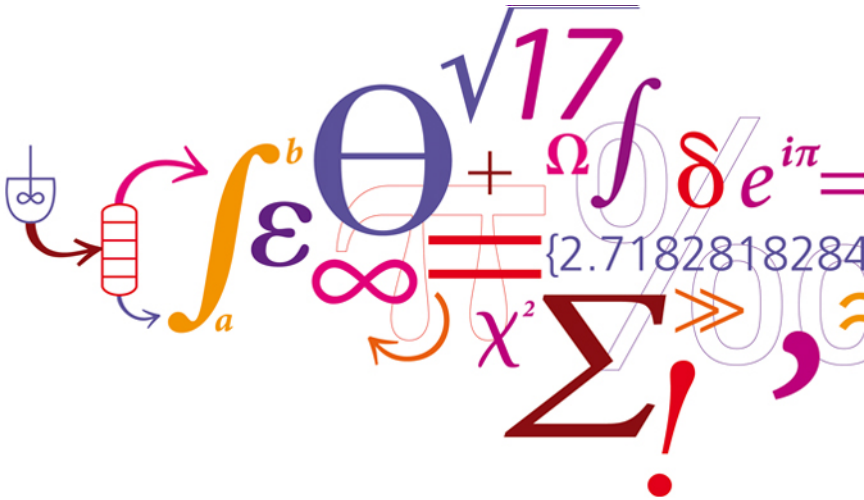


DTU Chemical Engineering
Department of Chemical and Biochemical Engineering

Overview

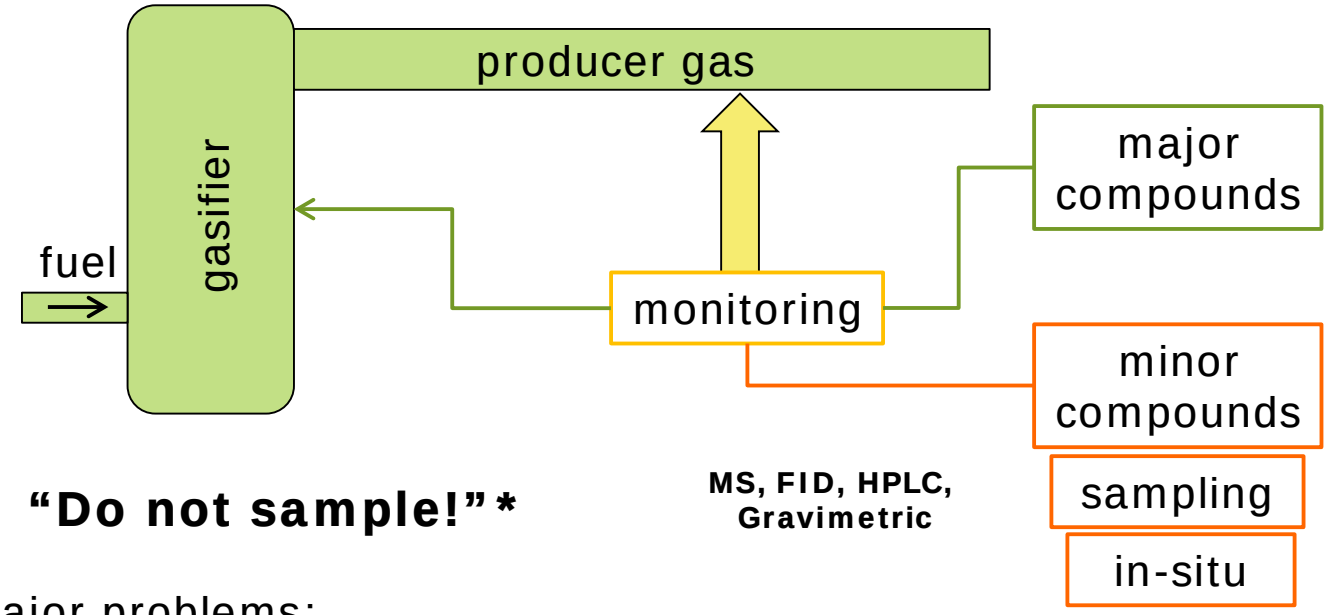
1) Motivation for Optical Diagnostics

2) Introduction to Optical Absorption Spectroscopy

3) Optical Absorption Spectroscopy in action
   a) Build-up of a database
   b) Challenge handling at gasifier measurements

4) Conclusion

Motivation



state of the art

CO, CO_2, H_2, CH_4

H_2O?

BTX, Phenols, PAHs, S-containing, N-containing, etc.

Importance depends on gasifier and application

MS, FID, HPLC, Gravimetric

"Do not sample!"*

Major problems:

1) Storage/transport of samples
2) Calibration
3) Unknown influence of
   - temperature drop (esp. cold spots)
   - tar/gas/particle filters

Optical spectroscopy can circumvents these problems

Development needed!

*Markus Kleinhappl @ the Gas Analysis Workshop 2014 in Berlin

What are we doing?

Method: Absorption spectroscopy (UV and IR) by extraction and in-situ

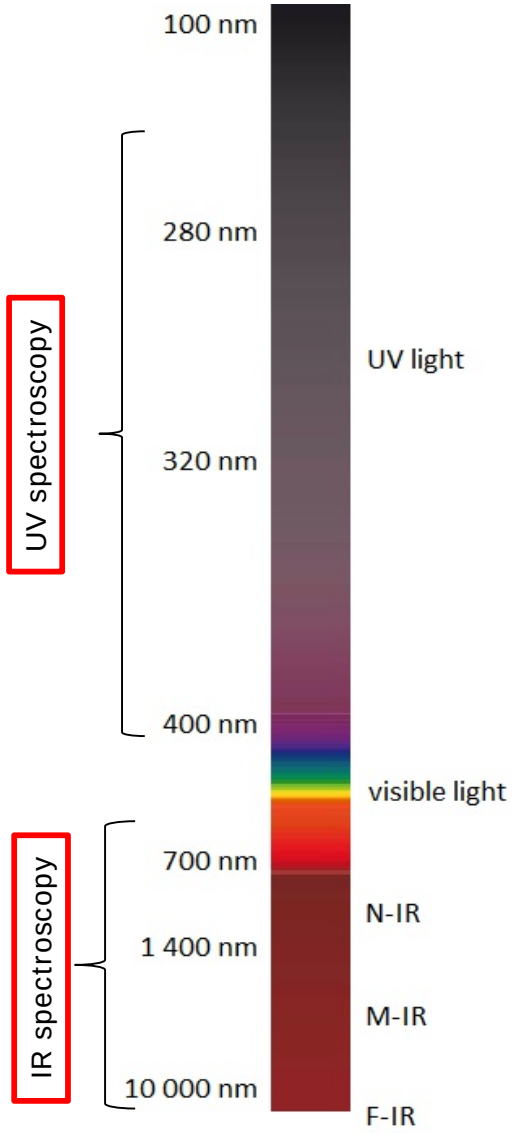
Compounds: Phenol, naphthalene, sulfur compounds, water, ammonia, hydrogen chloride

Objectives:

A) Laboratory experiments
- Obtaining pure spectra for build-up of database

B) Pilot scale gasifier experiments
- Identification and quantification of important compounds
- Evaluation of technical possibilities
- Verification of advantages

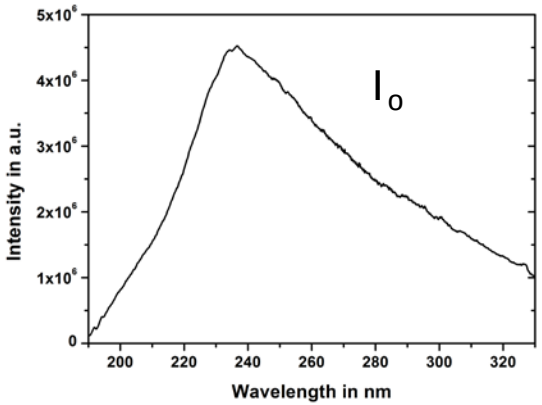
C) Demonstration gasifier experiments
- Evaluation of industrial problems



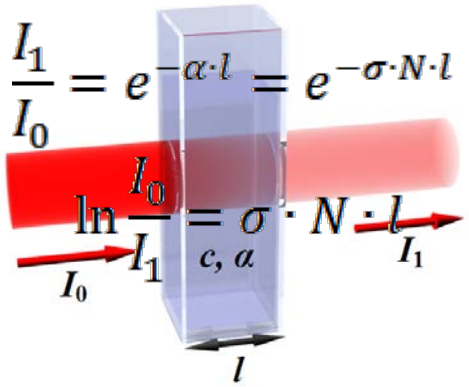
Introduction to optical absorption spectroscopy – the principle

Example UV spectroscopy

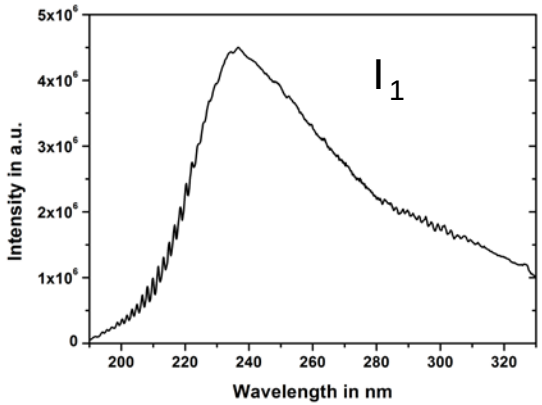
Spectrum w/o absorption



Lambert Beer Law



Spectrum with absorption

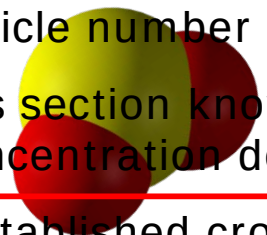


σ: absorption cross-sections (T, p, species dependent)
N: particle number

If cross section known
=> concentration determinable

Well established cross-section database needed!
a) through modeling (e.g. HITRAN if available)
b) through laboratory experiments

Light source



Absorbing Gas in a cell

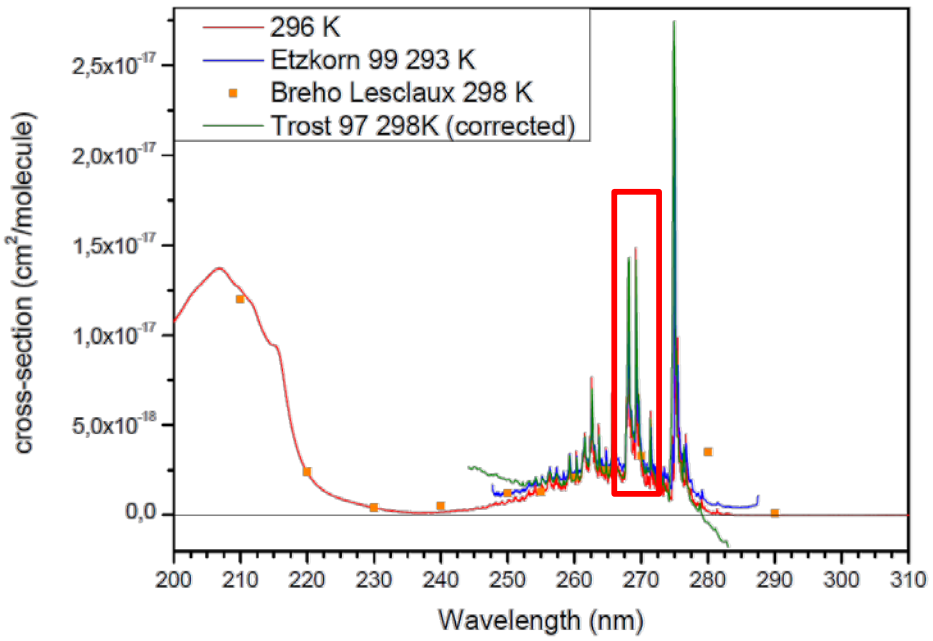
Spectrometer

How to establish a database in the lab
1) Validated gas cell

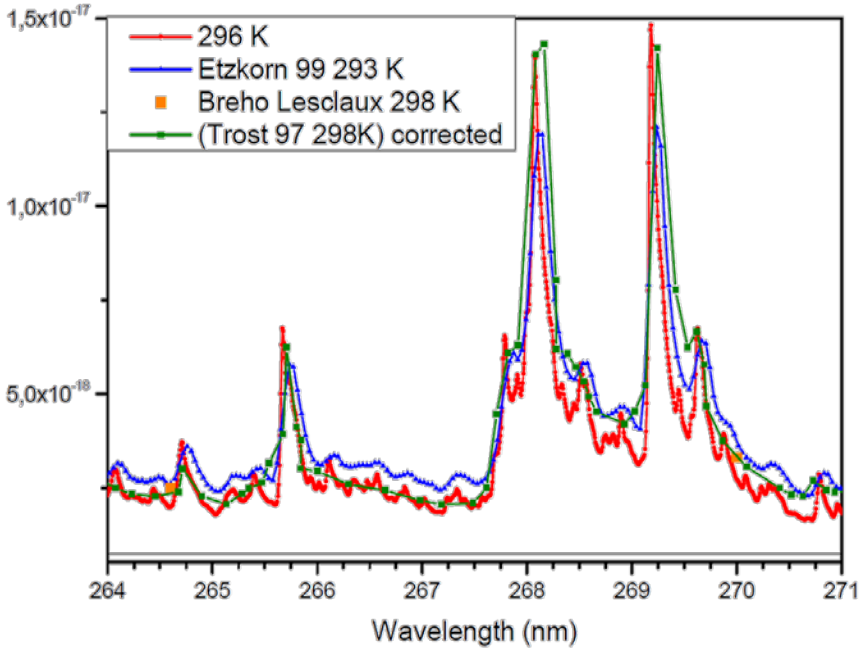
Different (maybe webinar) topic!

How to establish a database in the lab
2) Comparison with literature

Overall structure



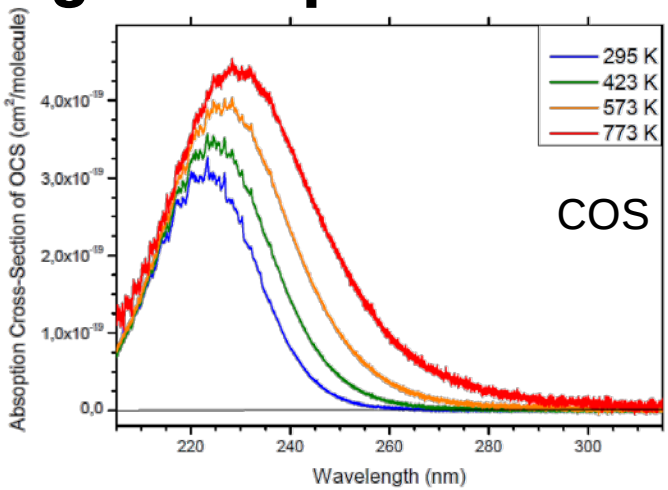
Fine structure

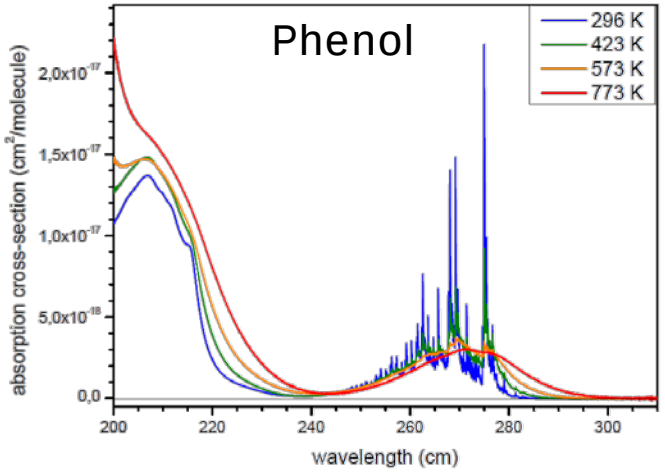


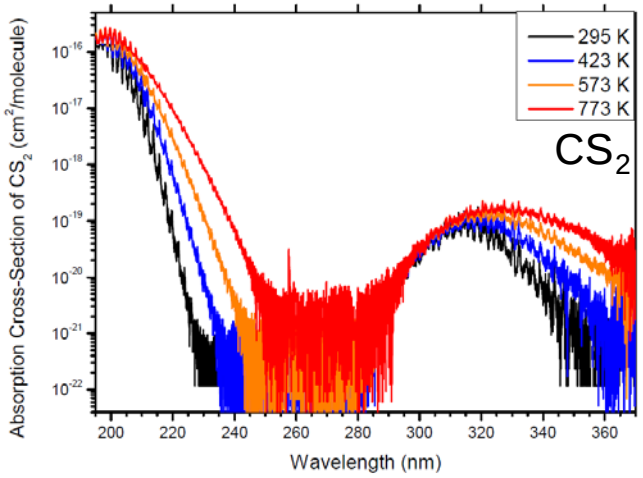
Excellent agreement at room temperature

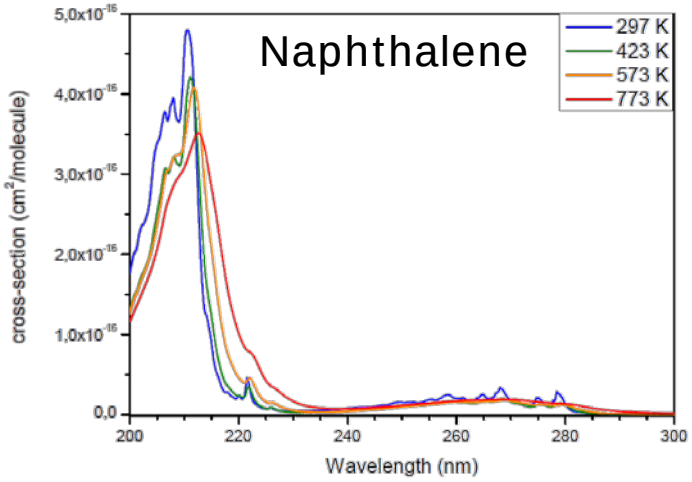
Higher resolution

How to establish a database in the lab
3) High temperature measurements









Possibility to determine concentration of important compounds at different T

Studies at the gasifier (LT-CFB)

Scope of measurements

Central question:

How to evaluate and circumvent the problems of sampling?

Topics for optical measurements:

- What are technological challenges?
- How can they be handled?
- Comparison of different measuring techniques
    - In-situ – Extraction
    - Sampling and GC/MS analysis (Helge Egsgaard, Zsuzsa Sárossy)
    - …

Technological challenges

Specifically for extraction:

- Cooling of gas
  - condensation of tars
  - blocking of small hoses

In-situ and extraction:

- Optical access
- Overlapping of bands
  - many varieties of tars (UV)
  - dust (UV)
  - water (IR)

Specifically in-situ

- Optical density of the gas (pathlength)
- Cleaning of windows

Setup of the Optical Experiments

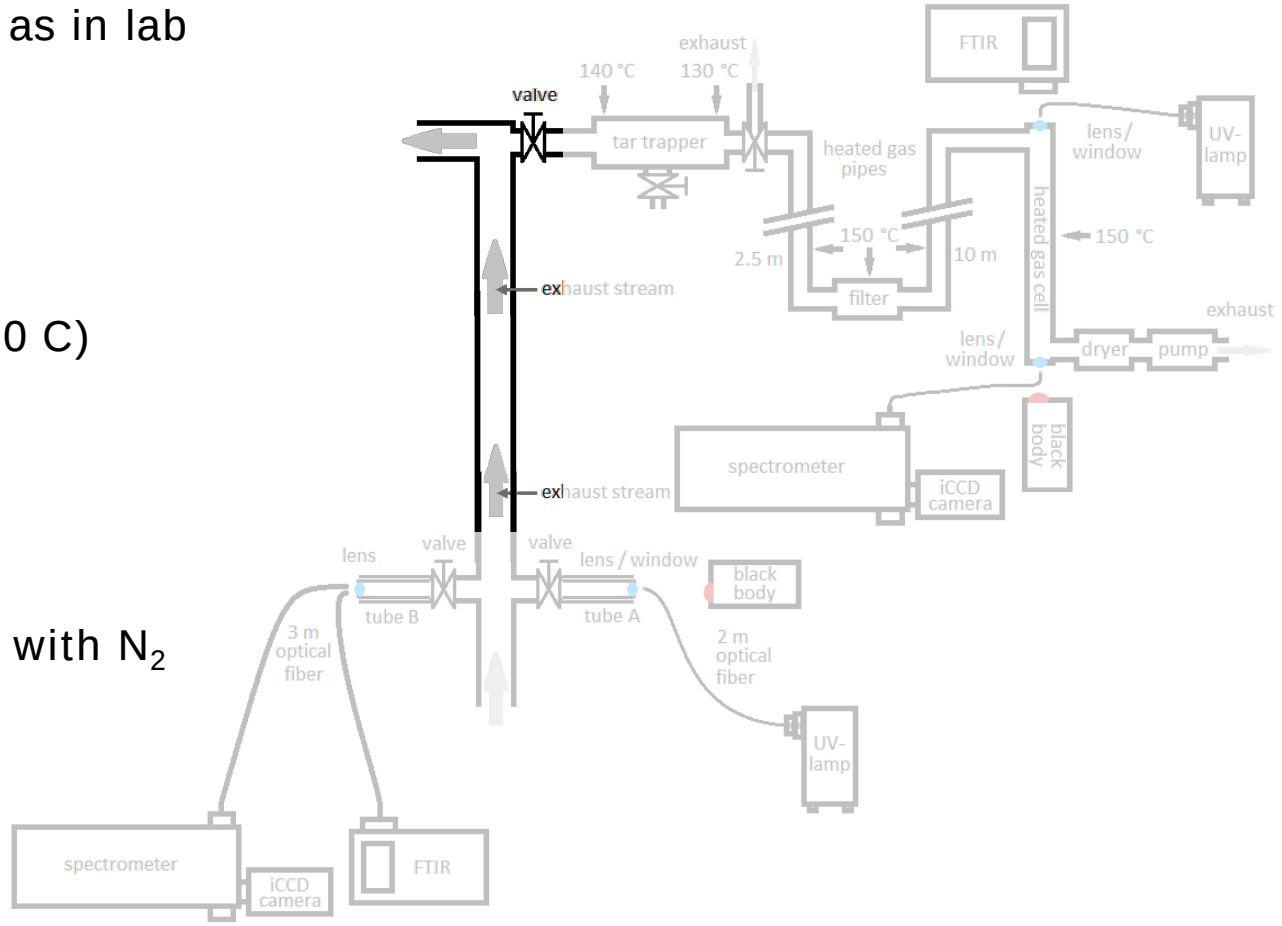
same optical equipment as in lab

Extraction

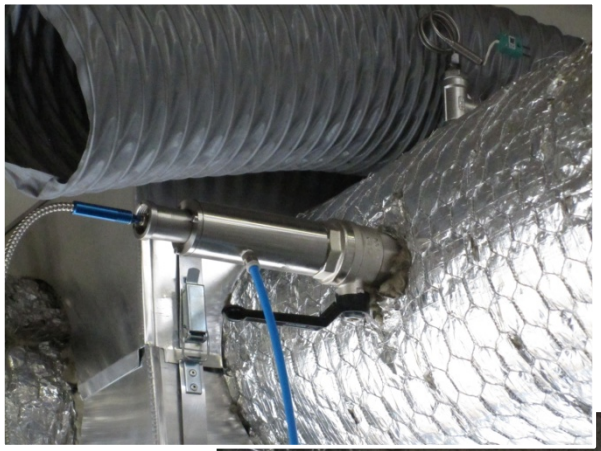
- extraction from 300 C
- tar trapper (at 130 C)
- Fully heated system (150 C)
- particle filter
- High resolution

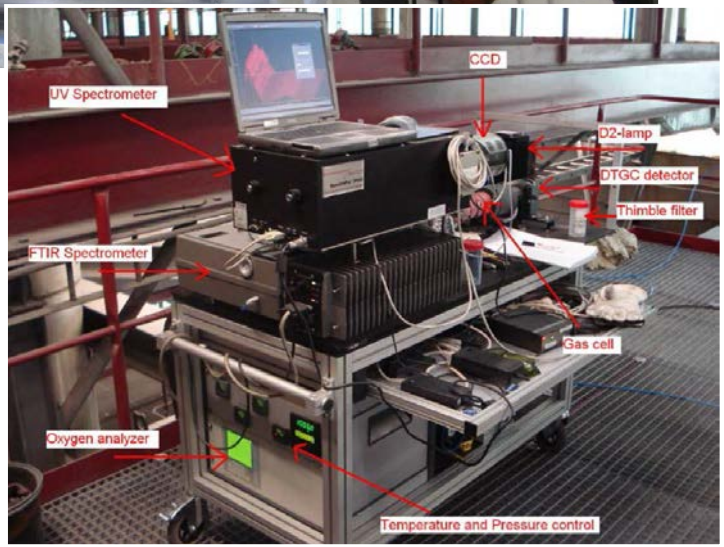
In-situ

- optical windows flushed with N_2
- variable pathlength
- use of optical fibers
- high intensity broadband light source

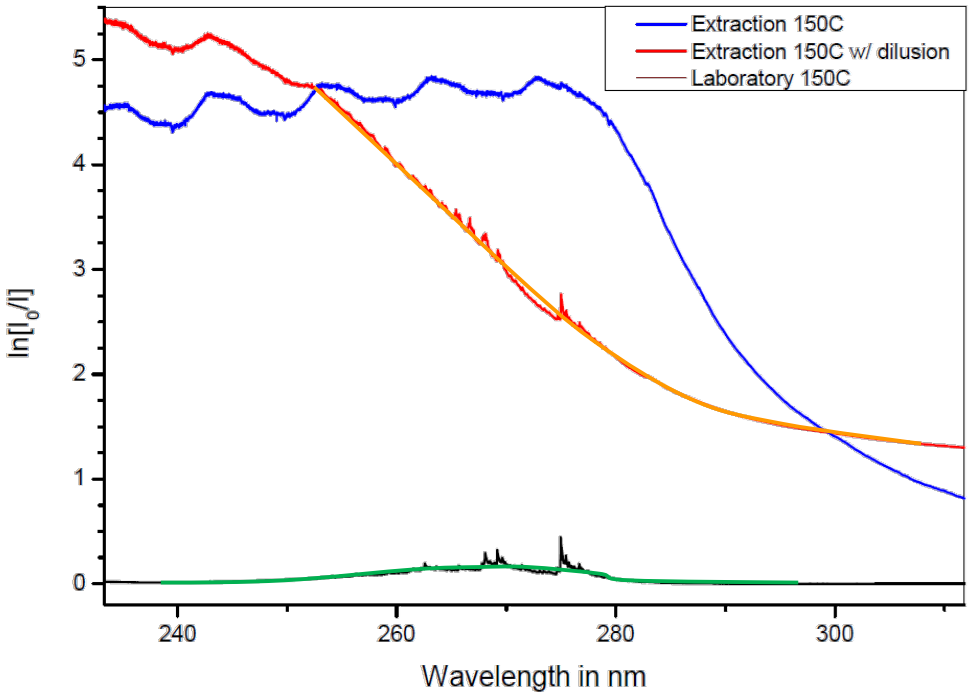


Setup at the gasifier





How to deal with overlaid signals?



Signal overlaid with other signals from e.g. water, tars and dust

Signal in full absorption

⇒ dilution with N_2

- Dilution factor from CO_2 IR signal

Water: high resolution + calculation and subtraction of water

Tars and Dust:

Background overlaying signal

⇒ differential optical absorption spectroscopy

- Subtraction of background
- Comparison only of fine structure

Conclusion

- In-situ measurements can circumvent sampling problems

- Optical absorption spectroscopy – a reliable and matured technology
- Large application possibilities (e.g. compounds)

But: New field of application
- rough environment, new compounds, etc.
  => Huge workload before first quantitative measurements

- Comparison with other standard techniques necessary
  - Measurements on two pilot scale gasifiers
  - Measurements up to demonstration plants (Pyroneer/Kalundborg) possible

The End

Thank You

Questions? Comments?