Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

TECHNISCHE UNIVERSITÄT DARMSTADT

Metrological validation of a new dTDLAS-Hygrometer

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Motivation

- Quality control during production and process control in the industry
- Humidity measurements inside industrial process plants
  - High temperatures and/or pressures
  - Harsh conditions (tar, dust, corrosive environment)
- Avoid sampling effects (condensation)
- dTDLAS as an optical gas transfer standard (calibration free)

New dTDLAS-Hygrometer of TU-Darmstadt

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- Advantages:
- In situ measurement
- High accuracy and precision
- High selectivity
- Robustness: Temperature stability > 200 °C — New
- Robustness: Pressure resistant > 10 bar — New
- Particle loaded or condensing atmosphere
- High temporal resolution – up to kHz
- Less process disturbance
- Flexible and simple system integration — New

New dTDLAS-Hygrometer of TU-Darmstadt

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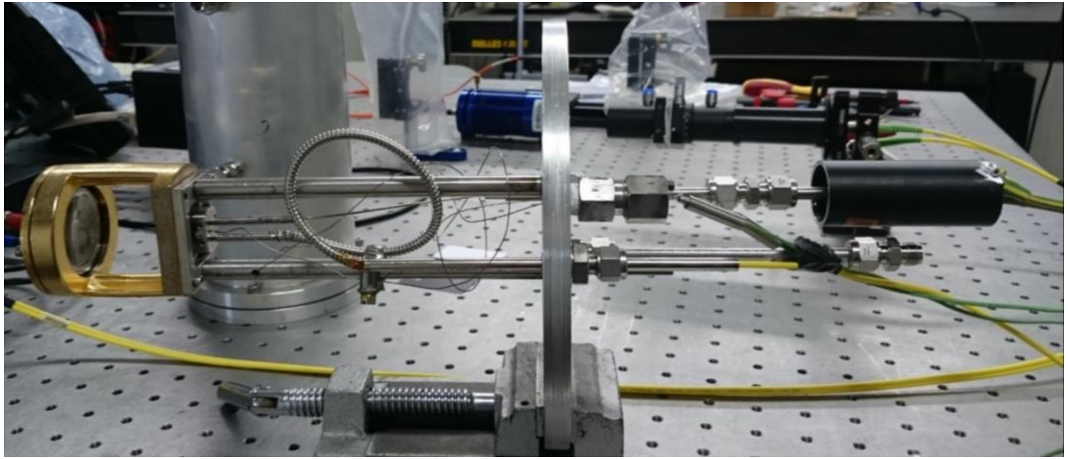
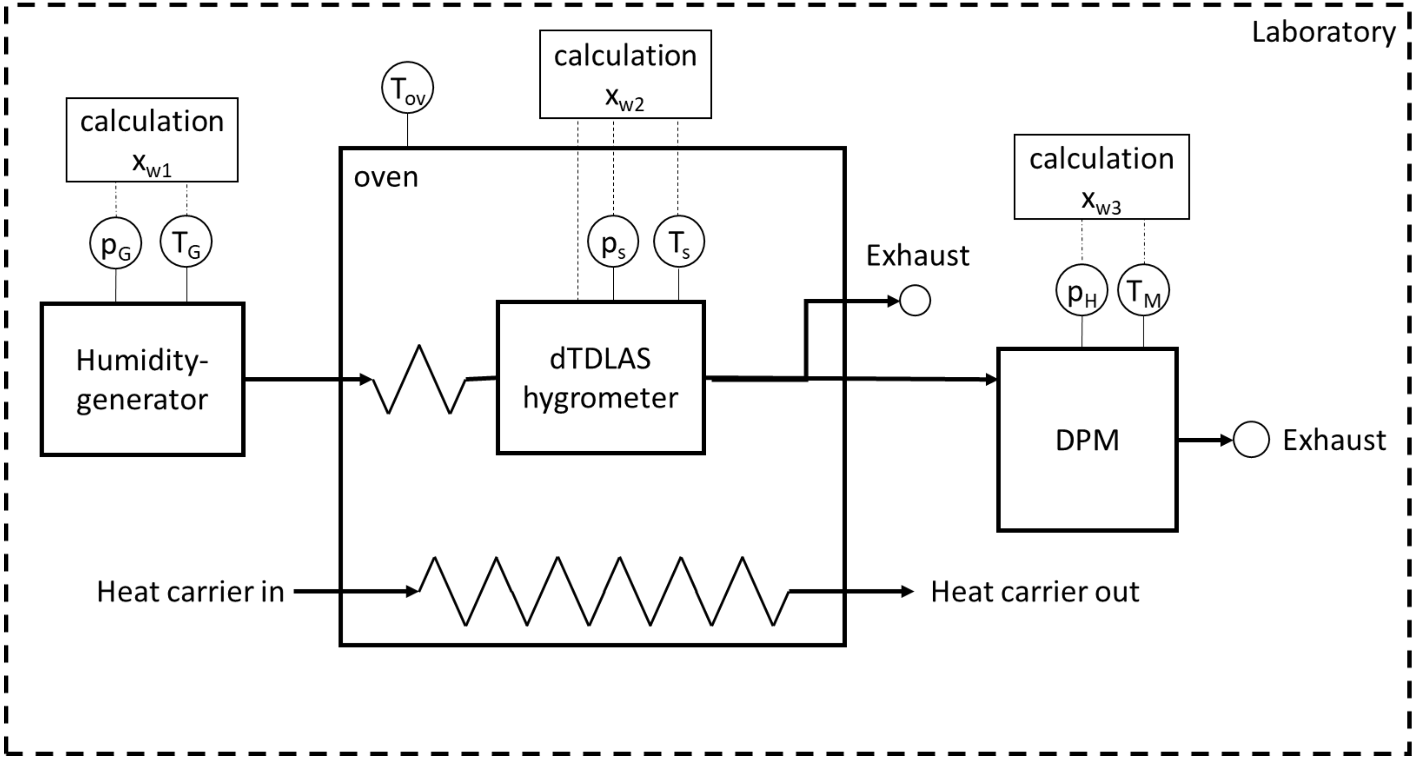
- Single ended configuration
- 3D printed chassis and optics
  (Additive Manufacturing)
- Completely fiber-coupled



Validation Procedure and Set-up at the PTB



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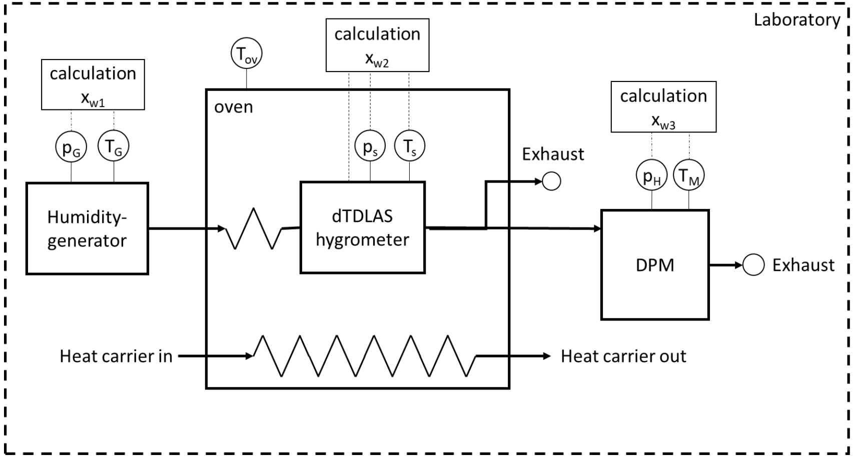
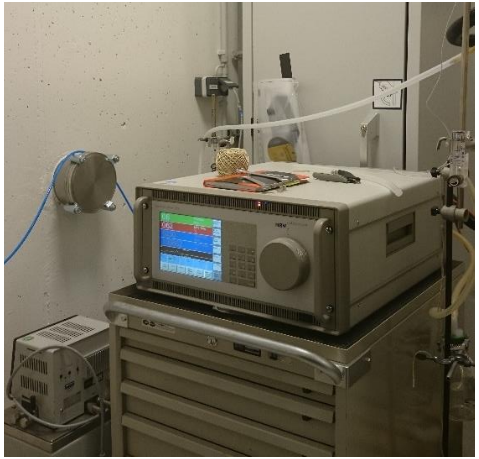
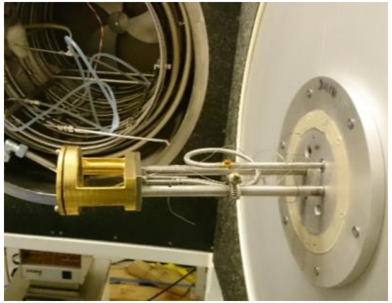
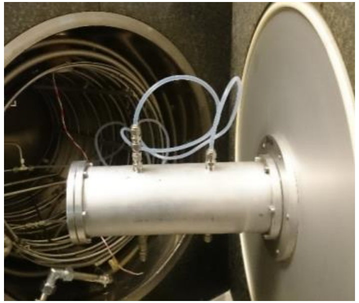




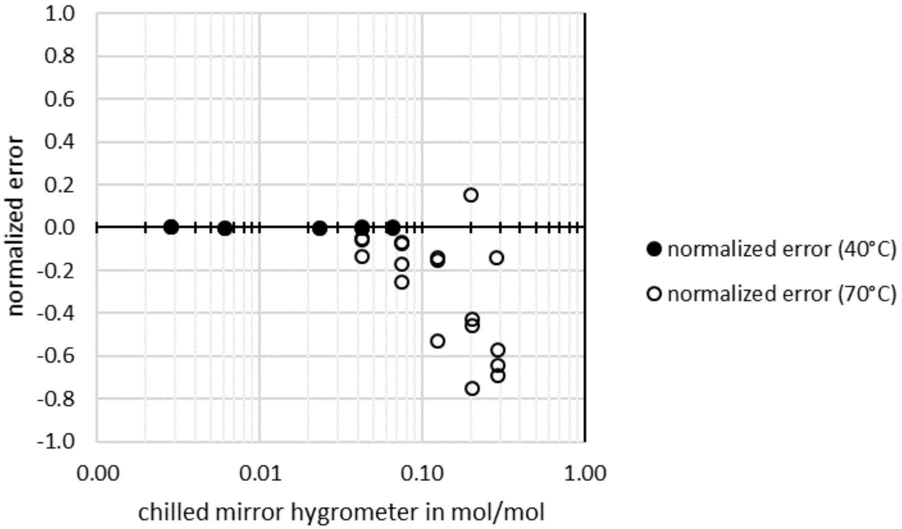




Validation of Set-up

- Set-up piping length of 16 m from the generator to the dTDLAS
  - Is any water vapor lost?
- Therefore the generated molar water content at the inlet (humidity generator) and at the outlet (chilled mirror hygrometer) are compared.
- Direct comparison of the chilled mirror hygrometer with the two pressure humidity generator (connected by a short heated piping < 2m) for evaluation.

Validation of Set-up



$$\text{normalized error} = \frac{\Delta x_w}{\sqrt{U_{HG}^2 + U_{CMH}^2}}$$

- All values are found in the range of ± 1 the normalized error
- This is in agreement with the residual found in direct comparison of CMH and HG

No significant influence of the set-up

dTDLAS vs. Chilled Mirror Hygrometer

Linearity and relative deviations tested

- At 40°C and 70°C with a dry gas flow of 4 l/min
- In the relative humidity range of ~0 to 98 %RH
  - 3000 ppm to 28 vol.% water vapor

First results:

- No relative deviations found larger than 5 %
- Detailed results will be published soon

Traceability:
Chilled mirror hygrometer traceable back to a primary standard

OUTLOOK: High-speed in-situ dTDLAS for dynamic calibrations

Motivation:

- Difficulties in the metrological evaluation of the temporal behavior of commercial hygrometers under rapid humidity changes
- Metrological characterization of response time?
- Dependence of dynamic behavior on:
  temperature, step height, flow rate?
- Comparison of different measurement principles?

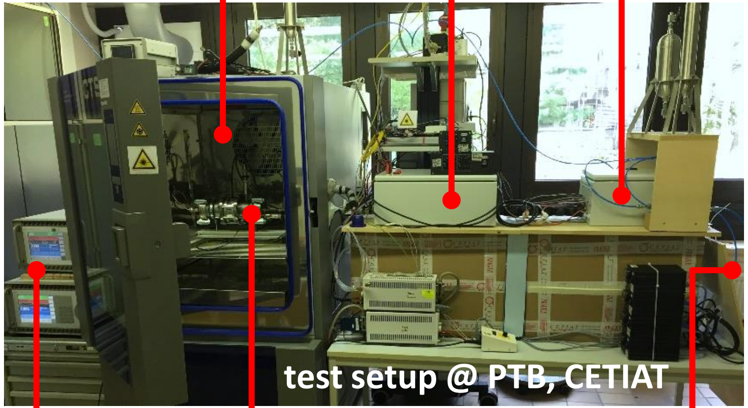
IDEA:

- Step-Change Humidity generator
  PLUS
- TDLAS in situ hygrometer as *sampling-free* *first-principle-based* reference hygrometer with well over 10 Hz temporal resolution

High-Speed dTDLAS-Set-up for dynamic calibrations

climate chamber

CETIAT fast-step humidity generator
valves flow controller



dew point meter (reference)

PTB measurement chamber with dTDLAS (reference)

humidity source

WORK IN PROGRESS

Results upcoming
stay tuned

Or contact us
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(partially based on earlier results from other EMPIR projects and PTB internal studies)

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Stand: 07/18