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12<sup>th</sup> July 2018, INRIM Torino-Italy

#### Workshop Website

[https://www.empir-hit.eu/en/documents?facet\\_theme=Workshop](https://www.empir-hit.eu/en/documents?facet_theme=Workshop)

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<https://www.empir-hit.eu/>



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#### The authors are with the PTB working group



<https://www.ptb.de/cms/en/ptb/fachabteilungen/abt3/fb-34/ag-342.html>



<https://www.ptb.de/cms/en/ptb/fachabteilungen/abt3/fb-34/ag-341.html>

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## Validation of a calibration-free, high-temp dTDLAS-based humidity sensor by means of PTB humidity standards

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<sup>1</sup>PTB: Reference standard and evaluation of results

<sup>2</sup>TU-Darmstadt: Design and construction of the dTLAS

With additional dynamic tests in cooperation the CETIAT

### Abstract

Results of the collaborative study of TU-Darmstadt and PTB in the HIT project were presented at the final workshop at INRIM, Torino, Italy.

PTB has set up a system for the validation of dTDLAS-hygrometers which were developed by TU-Darmstadt within the framework of HIT. The calibration facility is designed to calibrate humidity in air measurement devices at temperatures up to 100 °C. The system was designed to perform validations and/or calibrations of a device under test like the dTDLAS-hygrometer from TU DA. Traceability was achieved by comparison to a primary humidity standard via a reference chilled mirror hygrometer.

The developed dTDLAS hygrometer was shown to yield relative deviations of less than 5 % as compared to the reference value. This is nicely confirming its capability to be used as a transfer standard. Based on PTB's validation result and on further validation performed at INRIM for temperatures above 100°C the dTDLAS hygrometer could subsequently be applied successfully at an industrial site within the project thus demonstrating the valuable capabilities of such dTDLAS systems for industrial applications.

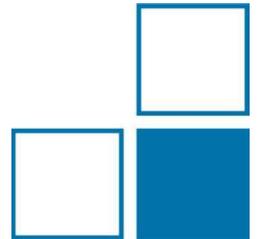
The measurement approach of dTDLAS-hygrometers complying with the TILSAM method<sup>1</sup> like the one from TU-Darmstadt in HIT is promoted by PTB 3.42.

<sup>1</sup> TILSAM, Traceable Infrared Laser-Spectrometric Amount fraction Measurement; URL: [https://www.euramet.org/Media/docs/projects/934\\_METCHEM\\_Interim\\_Report.pdf](https://www.euramet.org/Media/docs/projects/934_METCHEM_Interim_Report.pdf)

# Metrological validation of a new dTDLAS-Hygrometer

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Luigi Biondo and Steven Wagner – TU-DA



HIT – Final Project Meeting Torino, Italy July 2018

## 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

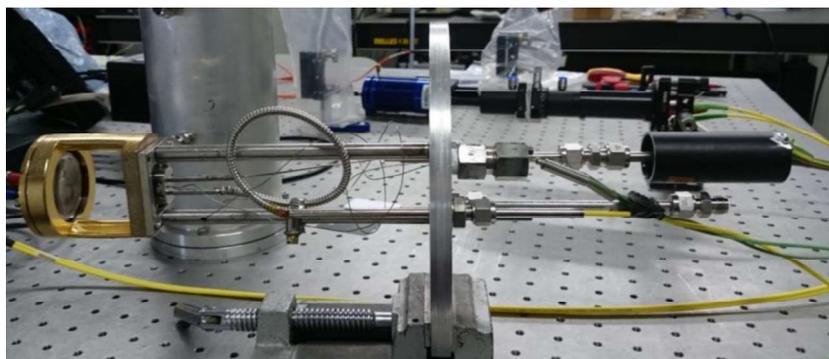


- Advantages:
- In situ measurement
- High accuracy and precision
- High selectivity
- Robustness: Temperature stability  $> 200\text{ }^{\circ}\text{C}$  **New**
- Robustness: Pressure resistant  $> 10\text{ bar}$  **New**
- Particle loaded or condensing atmosphere
- High temporal resolution – up to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

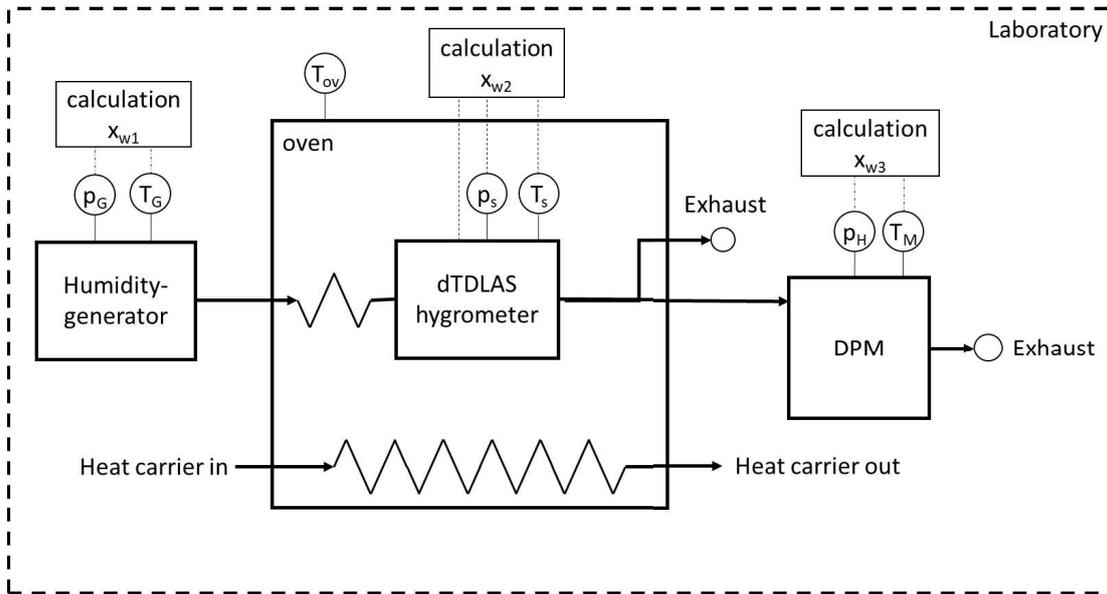
# New dTDLAS-Hygrometer of TU-Darmstadt



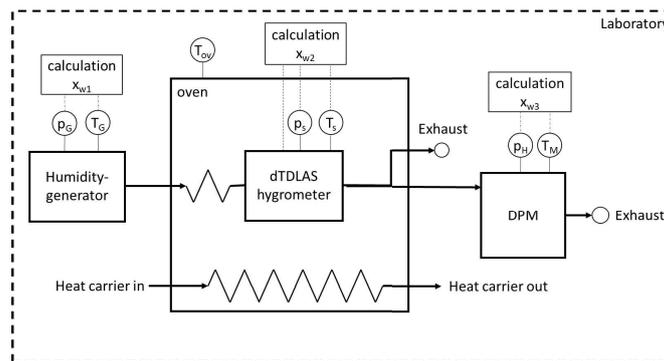
- Single ended configuration
- 3D printed chassis and optics  
(Additive Manufacturing)
- Completely fiber-coupled



# Validation Procedure and Set-up at the PTB



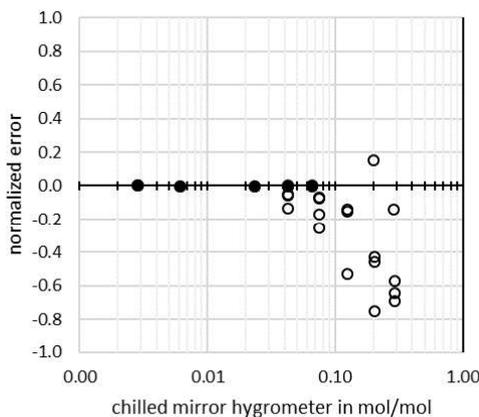
# Validation Procedure and Set-up at the PTB



# 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



● normalized error (40°C)  
○ normalized error (70°C)

- All values are found in the range of  $\pm 1$  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

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

# 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

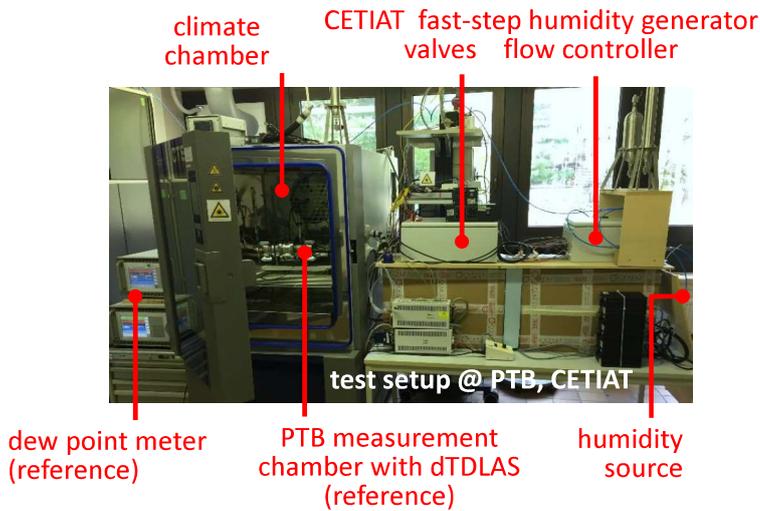


### □ Motivation:

- 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



*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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