NDIR Spectroscopy
The Benefits of Multi-Gas Sensors

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Twelve powerful brands within the Nynomic Group ensure successful solution development

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Growing markets within the m-u-t GmbH:
Spectrometric measurement and automation technology

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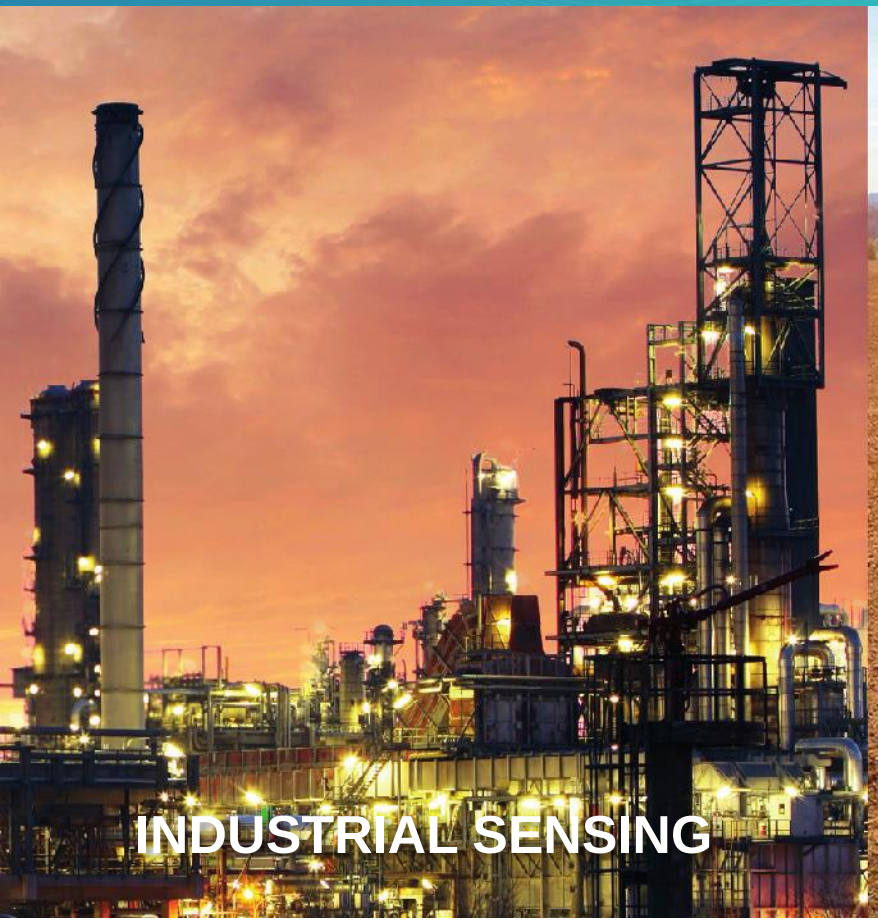

- Industrial Sensing
- Fire Detection
- Transportation

- Agricultural Technology
- Environmental Technology

- Medical Technology
- Lab Automation

What is NDIR?
And how does it work?

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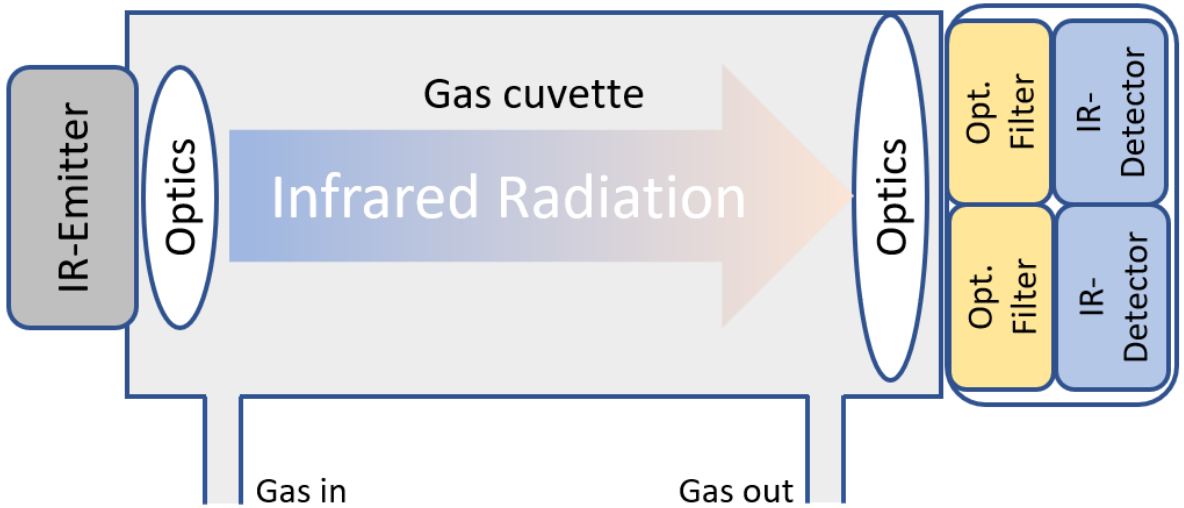
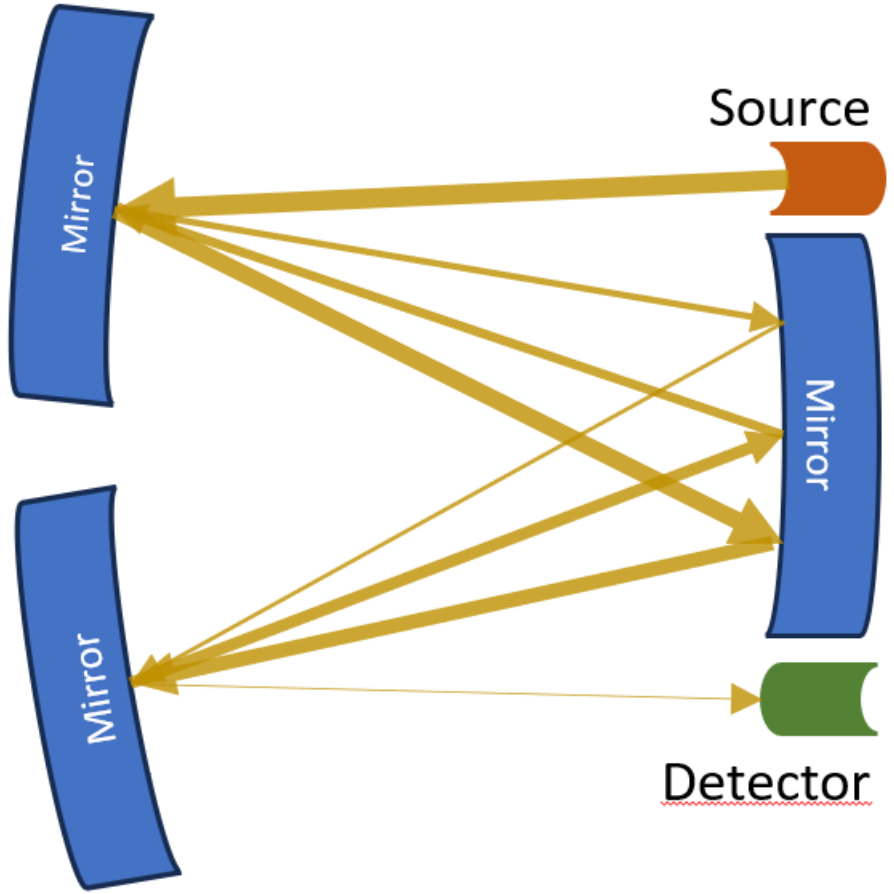
Measurement of attenuation of MID IR radiation due to gas absorption using:

- Broadband IR-emitter
- Gas cuvette with suited absorption length
- Broadband IR-detector with dielectric bandpass filters

- Multireflection White cell[1)] to keep the module compact





1) named after J. U. White

Gas absorption spectra
Compensation of cross-sensitivities

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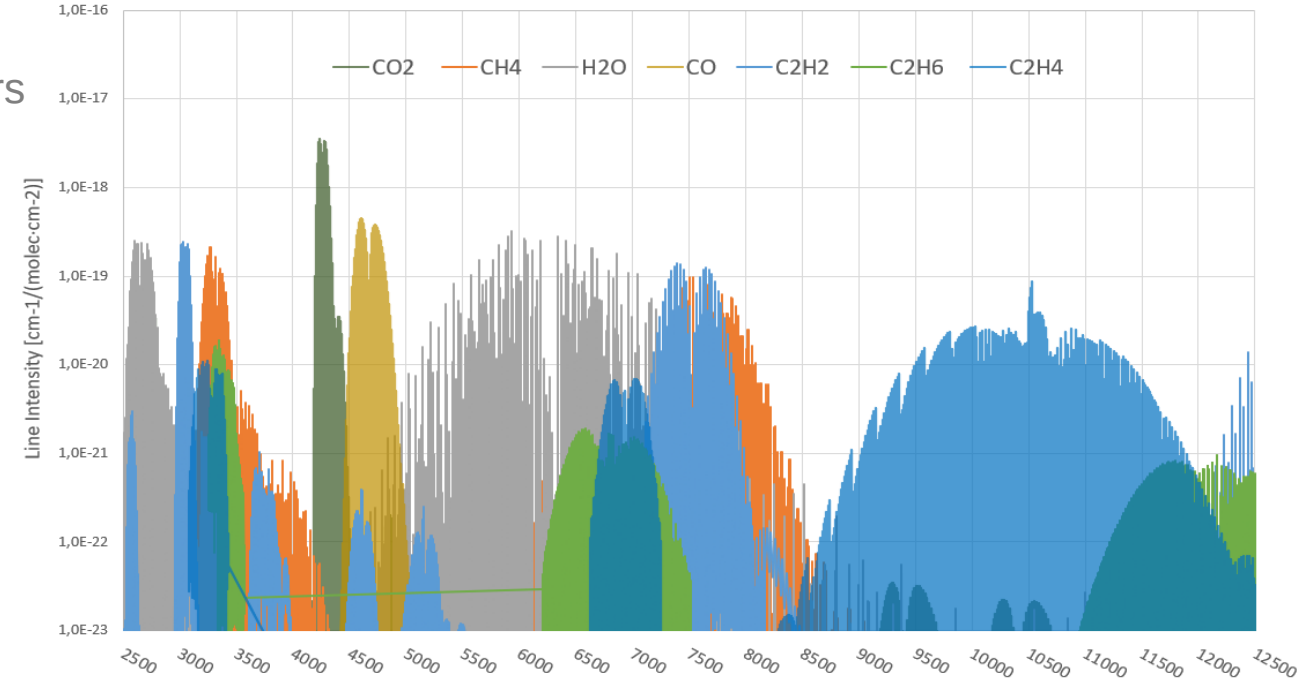
Gas Absorption

- Absorption follows the Beer-Lambert law, depending mainly on gas concentration and absorption length
- Strongest absorption bands are often in the MIR between 3µm and 12µm
- Water bands are dominant below 3µm and from 5µm to 7µm
- Absorption bands of different gases often overlap leading to cross-sensitivities
- Cross-sensitivities can often be reduced selecting appropriate filter bands
- Residual cross-sensitivities can be compensated using other NDIR channels or conventional sensors (e.g. humidity) and vice versa

The algorithms of the compensation are adjusted utilizing a multi-parameter calibration procedure (multivariate calibration).

$$\log\left(\frac{I_0}{I}\right) = \varepsilon_\lambda \times c \times l$$ *(Beer-Lambert law)*



I. E. Gordon, L. S. Rothman, R. J. Hargreaves, R. Hashemi, E. V. Karlovets, F. M. Skinner, *et al.*, "The HITRAN2020 molecular spectroscopic database", *J. Quant. Spectrosc. Radiat. Transfer* **277**, 107949 (2022). [doi:10.1016/j.jqsrt.2021.107949]

Multivariate calibration and data processing

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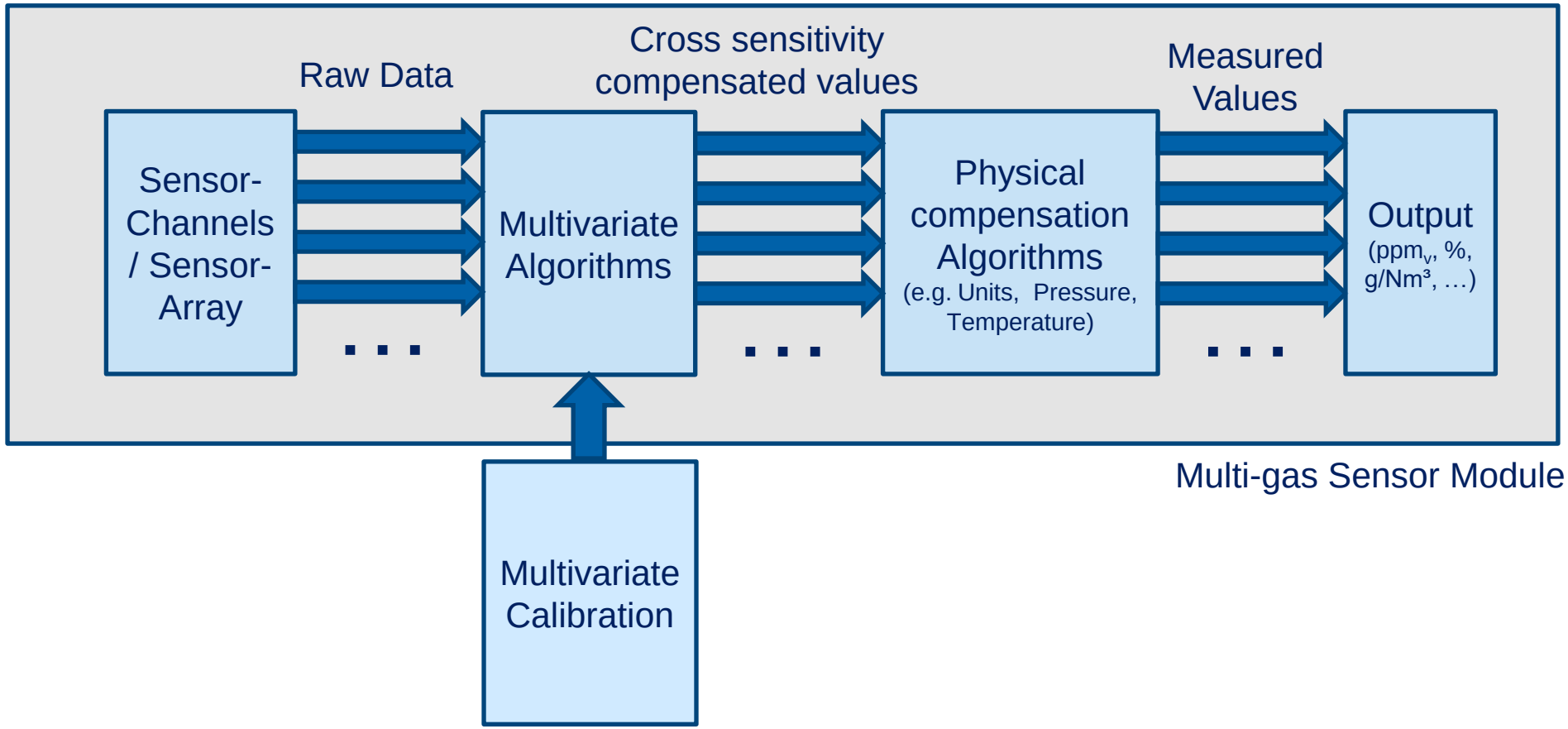
Functional Multi-Gas Platform Block Diagram



m-u-t OEM multi-gas platform
Core features

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OEM multi-gas sensor using optical NDIR technology

- Compact design with high absorption length applying multi reflection White cell
- Measuring range: few ppm to percent range (depending on gases and calibration)
- m-u-t proprietary 9-channel detector for up to 8 optical NDIR measurement channels
- No chemical reaction in the multi-gas sensor
- No onsite test gases necessary
- No moving parts, therefore durable and long-term stable
- Standard optical filters for e.g. CO, CO_2, CH_4, C_2H_2, C_2H_4, C_2H_6, C_3H_8, humidity (H_2O)
- Customizable optical filters for many other chemical compounds (gases and volatile liquids)

m-u-t OEM multi-gas platform
Additional features

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Optional conventional physical or chemical sensors

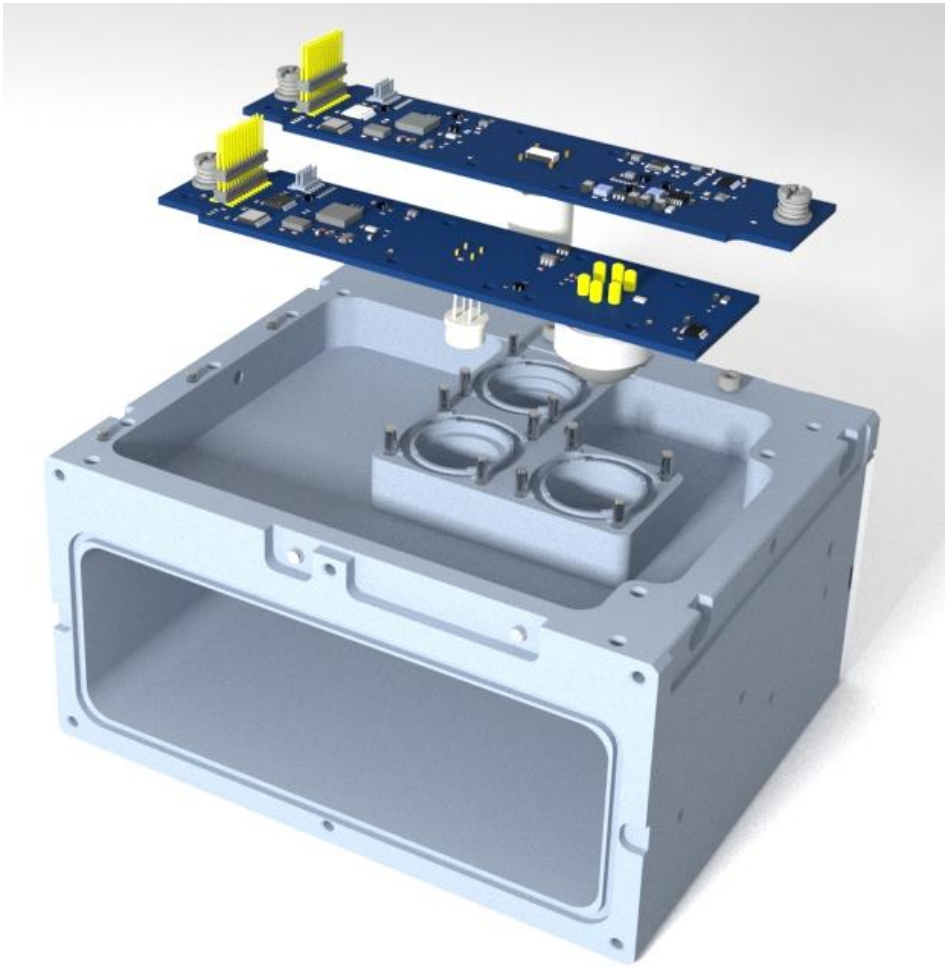
- Temperature (T), pressure (p), relative humidity (RH)
- H_2
- O_2
- Custom integration of chemical sensors

Measurement outside of the gas chamber

- Acceleration (a)
- pressure (p)
- Temperature (T)

Interfaces

- Power supply 24 VDC
- Data RS422 (RS485 optional)
- Process interface:
  - Flexible or rigid pipe connection
  - Flange
  - Specific adaptations
- Interface for temperature control (option)



Enhancing Transformer Safety…
… with Dissolved Gas Analysis (DGA)

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Application Example: High-power transformer monitoring

- Oil is used for insulation and heat transfer
- The molecules of oil and other insulation materials break up into smaller molecules due to transformer faults (fault gases)
- Analysis of dissolved gases (DGA) can be used for condition based maintenance:
  - Type of fault can be derived from the gases and their concentration ratios in the oil (e.g. overheating, partial discharge or arcing)
  - Gas concentration level or rate of gas generation indicates severity of fault
- Conventional DGA usually consists of sampling the oil and sending the sample to a laboratory for analysis
- Multi-gas sensors from m-u-t enable continuous online monitoring of transformers
- Online monitoring of electrical equipment is an integral part of the smart grid
- Oxygen O_2, Hydrogen H_2, Methane CH_4, Ethane C_2H_6, Propane C_3H_8, Ethylene C_2H_4, Acetylene C_2H_2, Carbon Monoxide CO and Carbon Dioxide CO_2 are measured simultaneously

What can m-u-t do for EPIC members and their customers?

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- Develop product ideas and bring them into series production as an OEM manufacturer
- Integrate IR detectors and IR emitters with other measurement principles to OEM sensor modules
- Support and spar with extensive knowledge of gas measurement technology
- Provide spectroscopy solutions from UV to MIR

What can EPIC members do for m-u-t?

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- Approach m-u-t as a development and manufacturing partner for new projects
- Challenge m-u-t with ideas for applications of multi-gas sensors

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