SPECTRO.sens

A new approach to industrial gas analysis

Optical measurement methods have been established in industrial gas analysis for many years and are also an integral part of Wi.Tec-Sensorik GmbH's product portfolio. The NDIR method enables a wide range of different gases to be detected with a high degree of accuracy. The requirements for measurement accuracy, detection limits and stability are constantly increasing in some areas of application, making technological improvements essential. The laser-based SPECTRO.sens gas measurement module (TDLAS) represents a significant step in this direction and is designed to effectively complement existing measurement capabilities in the NDIR field.

Measuring principle of the SPECTRO.sens

Optical gas measurement methods make use of the property of molecules to absorb infrared radiation. To do this, a beam of light is passed through a cuvette of length L containing the gas mixture to be analysed. The aim is to determine the concentration c of the gas being measured. This is calculated using Lambert–Beer's law [1]:

$$U(c) = U_0 \cdot e^{-\alpha \cdot c \cdot L} \quad [1]$$

Here, U_0 is the measurement voltage at the radiation receiver (5) with nitrogen in the analysis cuvette, U(c) is the measurement voltage with the gas mixture to be analysed in the analysis cuvette, α is the absorption coefficient of the measurement gas, and L is the geometric length of the analysis cuvette. As the laser beam passes through the analysis cuvette twice, the optical path length is thus doubled to 2·L.

Rearranging this equation in terms of c yields the equation for determining the required gas concentration c:

$$c = -\frac{ln\left[\frac{U(c)}{U_0}\right]}{\alpha \cdot L} \qquad [2]$$

Using the parameters U(c), U_0, the length L and the absorption coefficient α specified in the literature, the exact gas concentration c can be calculated. As the pressure and temperature in the analysis cuvette affect the gas density, this error must be eliminated by applying an appropriate correction. The result is a highly accurate and long-term stable gas analysis.

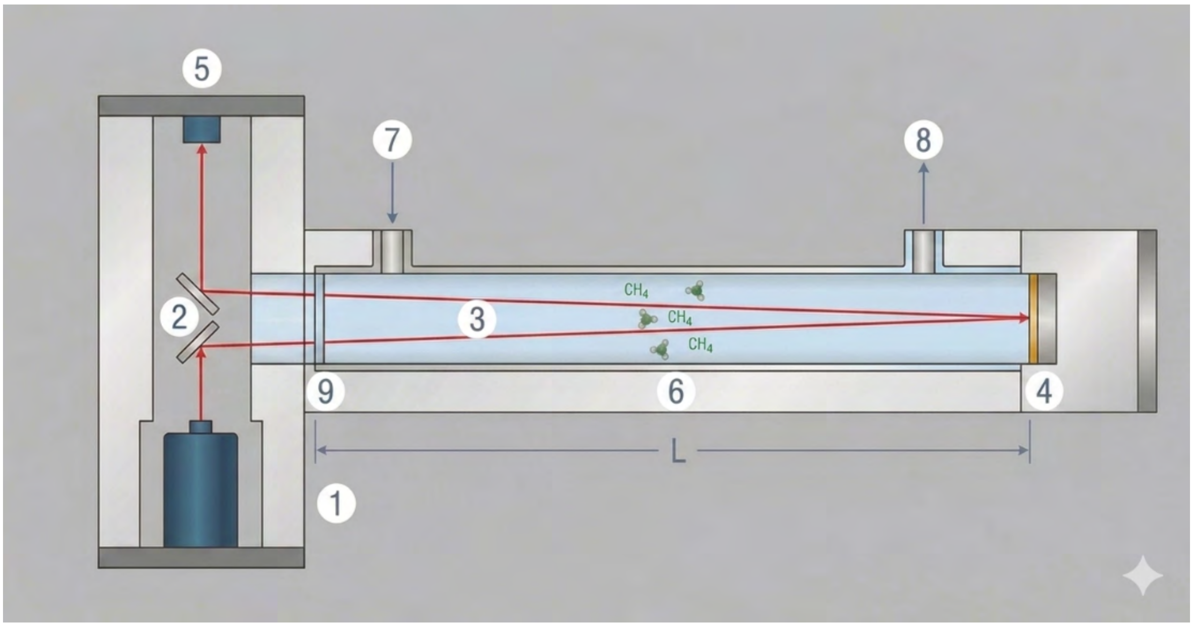

Fig. 1: Optical path of the SPECTRO.sens with 1. Tunable laser diode, 2. deflection mirror, 3. laser beam in the analysis cuvette, 4. deflection mirror, 5. radiation detector, 6. analysis cuvette (AK), 7. gas inlet, 8. gas outlet, 9. window to the analysis cuvette.

Design of the SPECTRO.sens

The gas analysis described is carried out by the SPECTRO.sens in the NIR band around 1.667 µm. This band (Fig. 2) is completely free of interfering absorption lines, such as those from water vapour (H_2O) and other hydrocarbons (HC). Gas measurement can be carried out using any absorption line within this band. For this purpose, the strongest lines are usually used, such as the line at 1.651 µm. During operation, the laser is tuned to one of these absorption lines using the diode current, so that the spectrum of the absorption line lies within a range of 0.5 nm (Fig. 3).

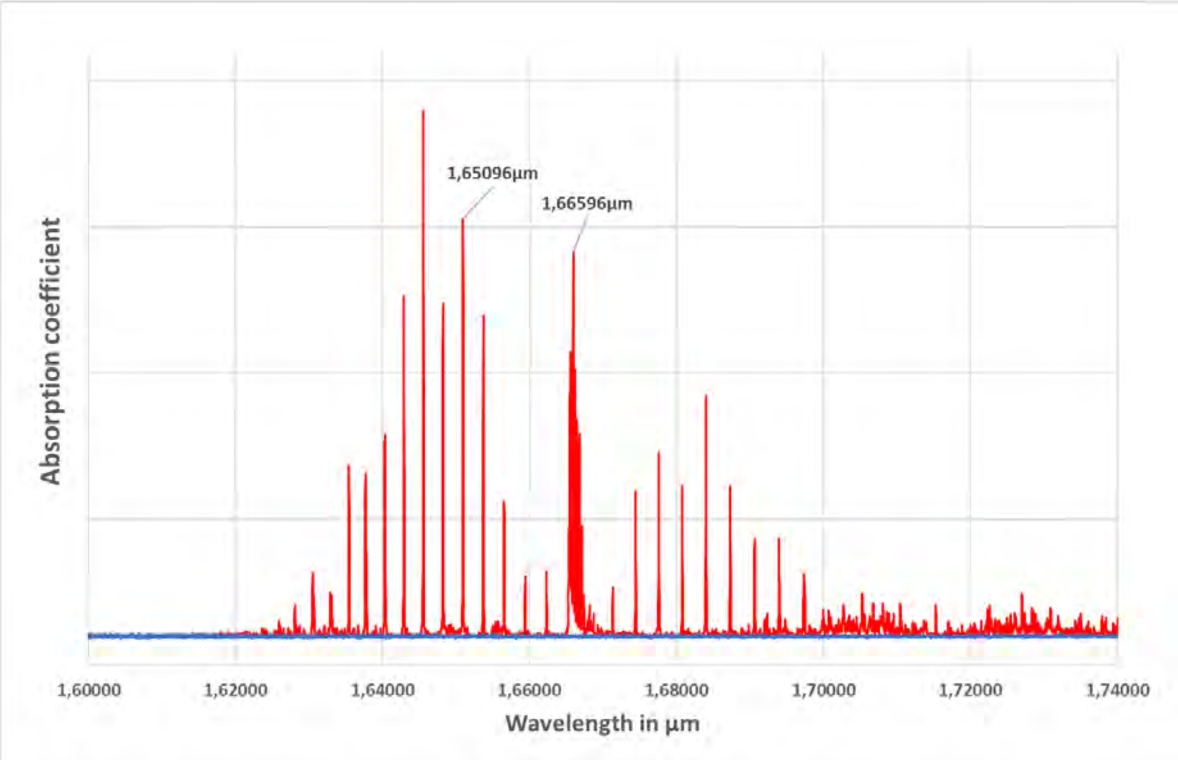

Fig. 2: NIR absorption spectrum of methane (red) at 1.667 µm. The water vapour spectrum (blue) shows no interfering with absorption lines in this spectral region [2].

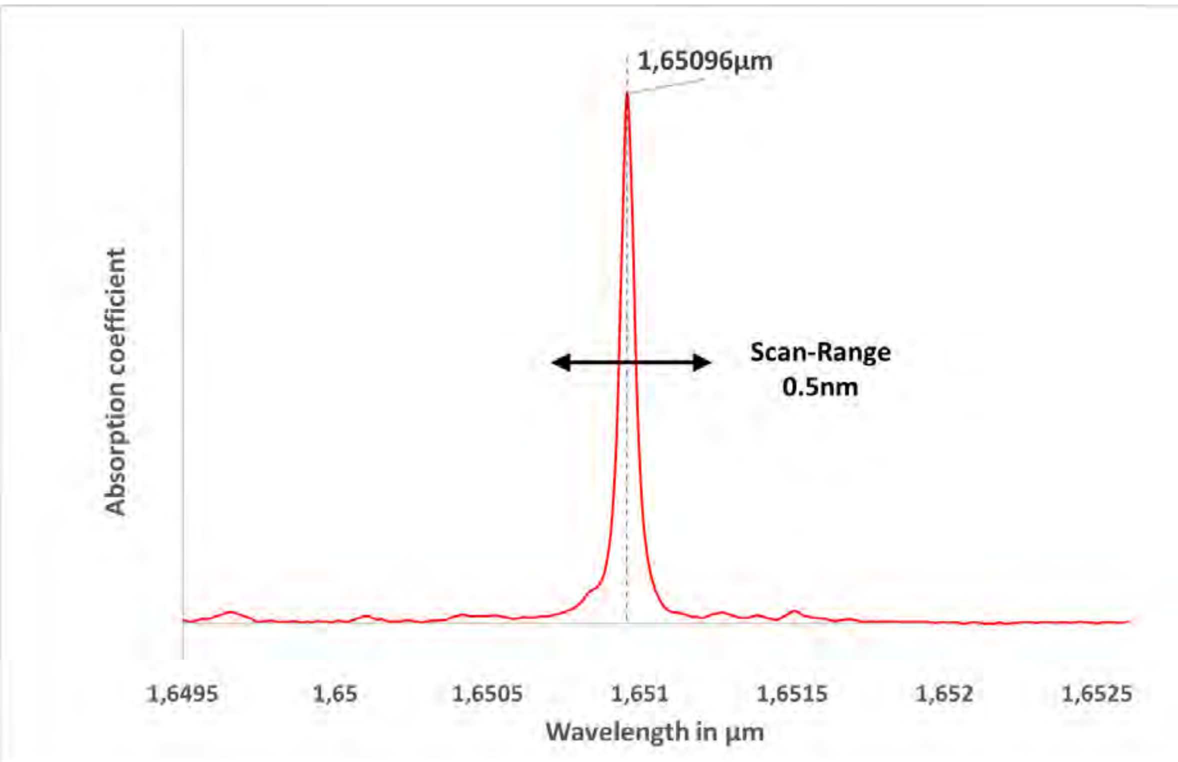

Fig. 3: CH_4 absorption line between 1.6485 µm and 1.6525 µm, with a scan range of 0.5 nm around the centre of the absorption line.

This spectral data is analysed in accordance with Eq. 2, thereby yielding the desired gas concentration c. As measurements are always taken outside the line during each scan, the zero value U0 is also obtained, which serves as a reference value. Undesirable drift phenomena, such as those commonly encountered in NDIR technology, are therefore effectively compensated for. The SPECTRO.sens is thus characterised by high long-term stability and is therefore also very low maintenance. By design, zero-point or end-point adjustment is not required. This is a significant advantage over conventional NDIR technology. Furthermore, cross-sensitivities to other gases are very low or non-existent [3]. Even high concentrations (e.g. 100 vol.%) of ethane, propane or butane are effectively compensated for, so that no significant cross-sensitivities can be measured.

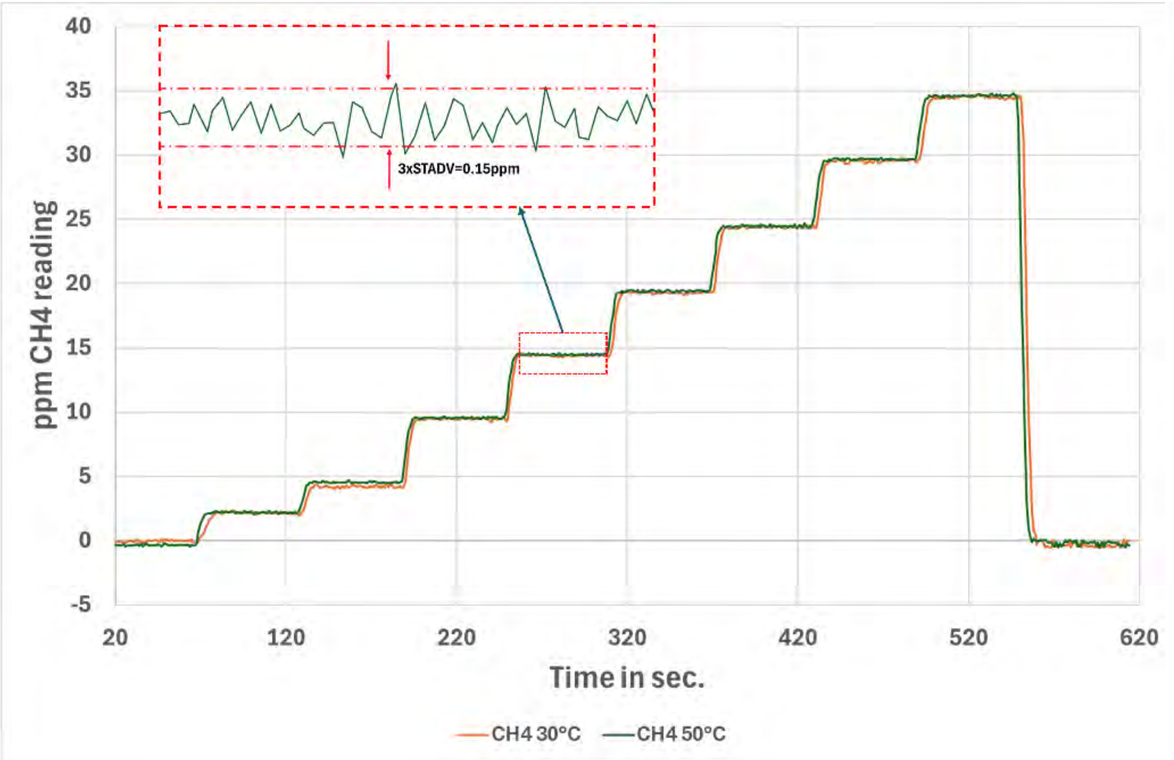

Fig. 4: Recording of the calibration curve for 0 ppm, 2.5 ppm, 5 ppm, 10 ppm...35 ppm CH_4 in N_2.

The optical bench of the SPECTRO.sens is shown in Fig. 5. It is stabilised at an operating temperature of 50°C using several heating elements, thereby preventing any influence from external temperature changes. In Fig. 4, the calibration curve was recorded in 5 ppm increments at 30°C and 50°C. Both recordings are identical, meaning that the influence of temperature is also negligible. Furthermore, this stabilisation prevents condensation (falling below the dew point) from forming in the analysis cuvette. A pressure and temperature sensor also measures the pressure and temperature values in the analysis cuvette, which are used for compensation.

To protect against external influences, the SPECTRO.sens is supplied in a Thermobox (Fig. 6), which consists of robust sheet steel housing and is fitted with thermal insulation on the inside. Both the gas supply and the electrical connectors can be connected very easily from the outside.

Fig. 5: The SPECTRO.sens optical bench with its associated signal processing electronics, integrated into a thermal housing (Thermobox TBH)

Fig. 6: Thermobox with integrated SPECTRO.sens assembly. Visible from the outside are the gas connections (4/6 hose), the power supply input (24 VDC) and the data communication port (RS232 and CAN interfaces).

Measurement characteristics

The measuring range for the SPECTRO.sens is specified as a maximum range and, for the configuration described, is 0–100,000 ppm CH_4 or 0–10 vol.% CH_4. Accuracy remains constant across the entire measuring range, enabling precise measurements in both the ppm and vol.% ranges. A subdivision into graduated measurement ranges (0–100 ppm, 0–1,000 ppm, etc.) is therefore not required. With a shorter analysis cuvette, a maximum range of up to 100 vol.% CH_4 would also be possible. The other measurement characteristics are listed in Table 1.

Table 1: Device specifications for methane measurement

Parameter	**Values / Range**
Measured gas	Methane CH_4
Measuring range	Low: 0-100ppm, High: 0–100,000 ppm
Detection limit	<0.15 ppm
Accuracy	2 ppm or 2% of the displayed value
Zero stability	±2 ppm per month
End-point check	Once a year
Cross-sensitivity (QE)	No cross-sensitivity to H_2O, CO_2, N_2O
T90% time	<5 s
Temperature range	5–50 °C (controlled@55°C)
Pressure range	500–1,100 hPa
Update rate	1Hz
Dimension LxWxH	345mm x 153mm x 103mm
Power	24VDC±2,5V

Applications

The laser-based SPECTRO.sens has a wide range of applications and can be implemented cost-effectively to meet future requirements. In particular, its low-maintenance operation, selectivity, measurement accuracy and high long-term stability are key requirements for many applications, all of which the SPECTRO.sens fulfils. Listed below are some of the areas of application for which the SPECTRO.sens can be used.

- ***Biogas plants***
  Continuous process monitoring of the methane content in raw biogas. High selectivity with respect to CO_2, H_2S and water vapour — typical components found in biogas.
- ***LDAR / EU Methane Regulation***
  Since 2024, oil, gas and mining companies in the EU have been required to carry out regular leakage detection and repair (LDAR) surveys. The SPECTRO.sens delivers the required measurement accuracy in the ppm range.
- ***Sewage treatment plants & wastewater***
  Monitoring of digester gas production, methane recovery from sewage sludge. Low-maintenance long-term measurement without regular zero-point calibration, ideal for unattended stations.
- ***Landfills***
  Mandatory monitoring of landfill gas emissions at the surface and in degassing systems. Detection of fugitive methane emissions as low as the ppm range
- ***Mining & Tunnel Construction***
  Methane monitoring in underground workings and tunnels. From 2025, the flaring of mine gas will be banned in the EU — precise measurement technology is mandatory.
- ***Industrial Safety***
  Gas detection control centres, monitoring service shafts and plant rooms. Fast T90 response time of under 5 seconds for safety-critical applications.
- ***Agriculture & Emissions Monitoring***
  Measurement of methane emissions from slurry systems, livestock housing and agricultural biogas processes. Growing market due to EU emissions reporting requirements.
- ***Food & Packaging***
  Inert gas monitoring in MAP packaging lines, leak detection on natural gas pipelines in production facilities. No cross-sensitivity to water vapour or CO_2.

Conclusion

With the innovative SPECTRO.sens, Wi.Tec-Sensorik GmbH offers a further innovation in gas analysis that provides significant advantages for certain gases. Its integration into the Thermobox described here makes it easier for OEM users to incorporate it robustly into their measurement systems or plants. In particular, the virtually maintenance-free operation of the SPECTRO.sens results in low operating costs and high reliability in gas analysis. Further gas measurements with the SPECTRO.sens, such as water vapour (H_2O), ammonia (NH_3), carbon monoxide (CO) and oxygen (O_2), are in the pipeline.

References

[1] Wiegleb, G.: Gas Measurement Technology in Theory and Practice, Springer Verlag Wiesbaden 2023
[2] The Hitran Database https://hitran.org/
[3] Guerreroa,J. Gambaa, M.: A Review of Theory and Practical Considerations of Tunable Diode Laser Absorption Spectroscopy Diagnostics.
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