Fraunhofer IPM

Breath analysis
Photothermal detection of trace gases

Sensitive substance detection in breath gas in real time

Fraunhofer IPM's MVP photothermal gas analyzer measures trace gas concentrations rapidly and sensitively – even in small sample gas flow volumes. This enables the real-time analysis of respiratory gases, visualizing concentration trends within a single breath.

The trace components of exhaled air contain a lot of information about the conditions and processes inside the human body. Fraunhofer IPM's MicroVolume Photothermal (MVP) gas analyzer quickly and sensitively measures such substances in this challenging matrix. This makes the MVP gas analyzer a novel and powerful tool for use in physiological and medical research and diagnostics.

Breath gas tests – fast and informative

When humans breathe, the inhaled air is enriched with a great number of substances of physiological origin. When we exhale, these substances are released together with the exhaled air. Nobel Prize winner Linus Pauling was among the first to describe a connection between volatile organic compounds in the respiratory air and various diseases. Even simple molecules, such as nitrogen oxide, methane or ammonia, can serve as biomarkers for the detection of diseases or metabolic disorders. Breath tests are non-invasive – unlike blood tests or biopsies – and the sample is delivered continuously, allowing for continuous monitoring, among other advantages. Measuring the trace components in human breath is technically challenging, for three reasons, though: Firstly, the relevant concentrations usually lie in the mid to low parts-per-billion (ppb) range. Secondly, breath gas forms a complicated background matrix; and thirdly, the sample volume of a single breath is just a few liters. Therefore, to date, only a small number of breath tests have been approved for medical applications.

Photothermal laser spectroscopy

Infrared laser spectroscopy is a powerful technique for the rapid, sensitive, and specific detection of substances. Conventional methods use multipass cells to create long absorption pathways within the sample and thus achieve low detection limits. These types of breath gas analysis methods have their

Typical specifications

- **Target substances**[1]
  NH_3, N_2O, CH_4, CO, HF, …
- **Limit of detection**[2]
  < 50 ppb
- **Time resolution**
  < 1 s
- **Sample gas flow**
  5–1000 ml/min

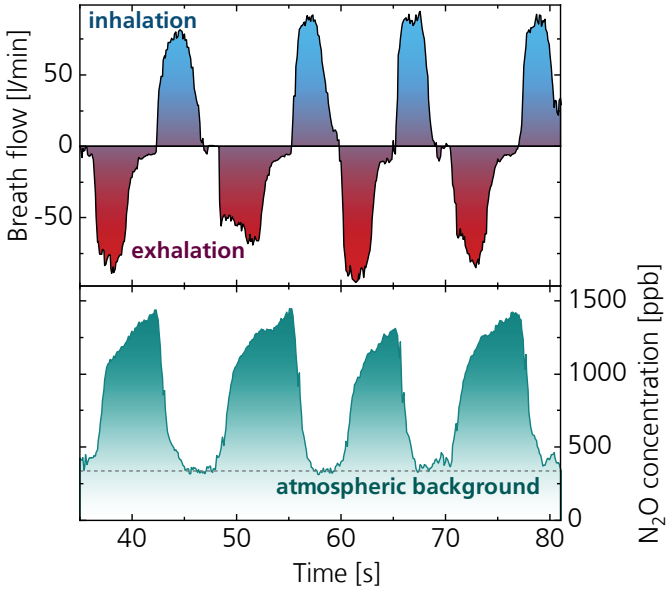
[1] freely configurable – depending on laser

[2] depending on the target substance

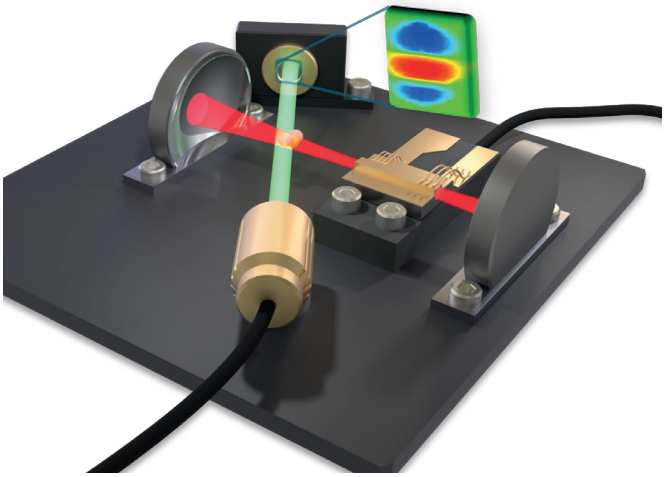
limitations, however, because of the sample quantities required to replace the gas volume within the cell. This problem can be avoided by using photothermal spectroscopy, which is closely related to photoacoustics and measures the heating of a sample instead of the attenuation of a laser beam. Fraunhofer IPM has developed and patented a method in which the target substance is detected by its heat response to a separate probe laser. The method allows detecting concentrations down to the single-digit ppb range within one second, while the sample volume can be limited to the size of the intersection of the two laser beams, which is just a few microliters. Optical readouts also enable bypassing various types of interference caused by the gas matrix, which often limit the use of photoacoustic systems.

Application benefits

Fraunhofer IPM's MVP gas analyzer has been designed as a platform for optical trace gas analysis in respiratory air. In addition to the photothermal sensor unit, the system also includes sampling from the respiratory stream through a portable breathing mask as well as secondary sensor technology (e.g. for measuring respiratory flow, temperature, pressure, etc.). The choice of spectroscopy laser allows the system to be configured for a variety of target substances. Sampling is continuous and independent of the respiratory cycle. Thus, concentration values in the exhaled air are directly and continuously referenced against the inhaled background concentration. The rapid gas exchange in the measurement volume allows resolving concentration curves even within individual breaths. This provides valuable additional information such as distinguishing between the origin of concentrations in the upper or lower respiratory tract.



***Example measurement:** Nitrous oxide (N_2O) as a metabolic product in the respiratory air. The MVP gas analyzer simultaneously measures the respiratory flow and the concentration of trace elements.*



***Measuring principle of photothermal spectroscopy:** A laser beam (red) is directed at the target substance and is absorbed by its molecules as heat is released. Local heating produces a characteristic pattern in a second probe laser beam (green), which looks similar to a heat flicker (magnified). This pattern can be detected with high sensitivity.*

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