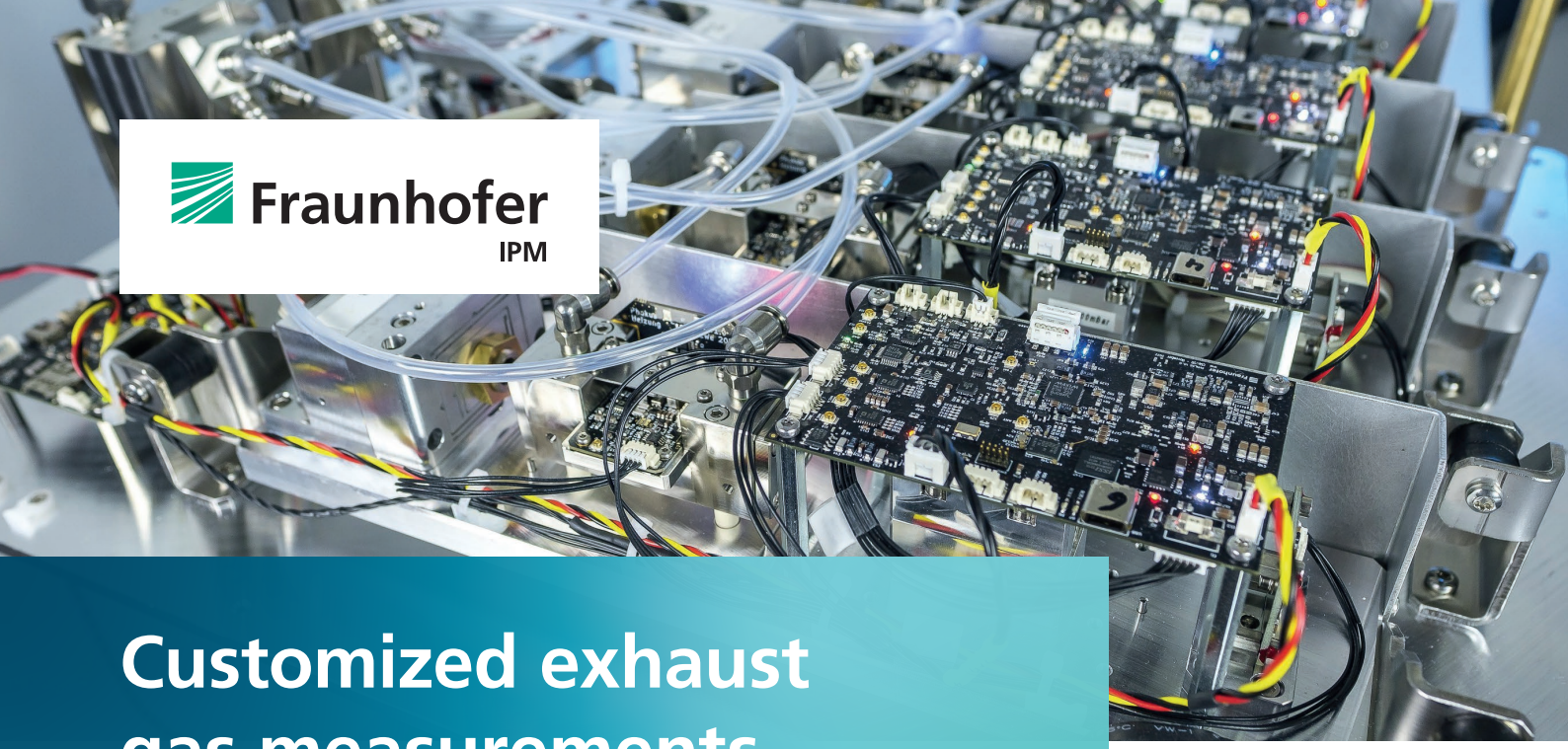


Fraunhofer IPM

Customized exhaust gas measurements

Tuneable diode laser spectroscopy for fast gas analysis

Novel laser-based measurement technologies, like photoacoustic gas detection modules for individual gas components, can either be integrated into the analyzer system or connected to the system as a remote unit.

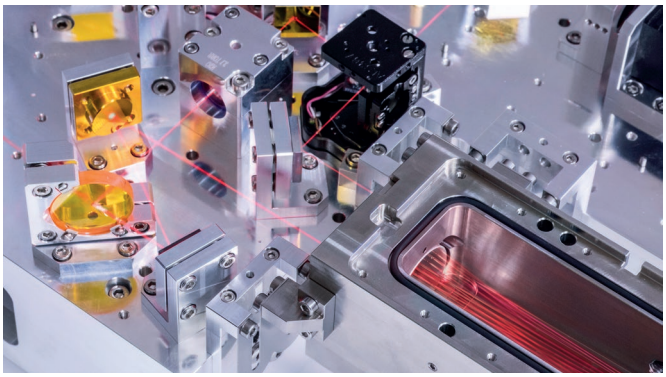
In November 2016, the German Government adopted the 2050 Climate Action Plan against the backdrop of the Paris Climate Agreement. The Plan provides guidance to attain the national climate targets in all fields of action. Specific attention is given to greenhouse gases such as carbon dioxides, methane, ammonia and laughing gas. Based on EU-legislation for example, the emission limits for automobiles are lowered continuously. Strict exhaust gas standards require innovative technologies in order to reduce traffic emissions even further.

Detection from ppm down to ppb

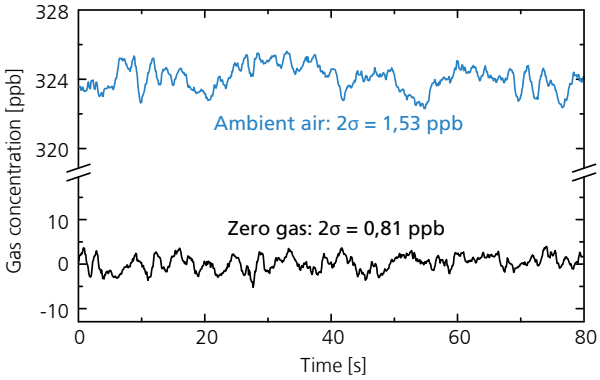
Fraunhofer IPM has developed a series of spectroscopic analyzer systems particularly designed for measuring exhaust gases. The systems are based either on the principle of laser-based transmission spectroscopy or alternatively on the principle of photoacoustic light detection. Photoacoustics has the advantage of simpler mirror optics and a very small sample volume. In a more complex version, these systems are able to simultaneously quantify the concentrations of gas components at different sampling positions with high selectivity and high time resolution. This enables the detection of short-time events and therefore tracking of the entire highly dynamic behavior of combustion or emission processes.

Depending on customer requirements, the systems can be adapted to different tasks. For analyzing fast processes, measurement cycles of up to 100 Hz can be realized. High-speed measurements are necessary for analyzing phenomena such as gas breakthroughs, e.g. at catalytic converters. Limiting factor for fast extractive techniques is the gas exchange time within the gas channels. In their fast version, the systems achieve detection limits of some parts per million (ppm). Depending on the relevant gas component, the system can be adapted for higher precisions down to a few parts per billion (ppb) at a speed of 5 Hz, which is perfectly sufficient for operation at engine test beds. Analyzer systems are designed for R&D and certification testing of low emission engines. Customers are OEM suppliers and testing facilities.

The laser-based analyzer systems can be designed with up to four parallel measurement channels. This is particularly interesting for the simultaneous analysis of varying gas compositions at different positions within the exhaust gas system of a car, e. g. before and behind the catalytic converter module. The focus lies, in particular, on gases like CO, CO_2, CH_4, NO_x, NH_3 and N_2O.



Optical setup including a multi-reflection cell. The red laser beam is used for adjustment in the mid infrared only.



Typical stability behavior of concentration values over time for gas signals, in this case ambient air, as well as the zero baseline (pure nitrogen).

Tunable laser sources, gas sampling and detector technologies

For selective gas analysis, wavelengths in the mid infrared regime between 3 and 11 µm are commonly used. To address this wavelength range, Fraunhofer IPM employs quantum and interband cascade lasers (QCLs/ICLs) as light sources. Typical tuning requirements are 0.5 cm^{-1} to scan over individual gas absorption lines with a repetitive modulation frequency in the order of kHz. To realize suitable absorption interactions between laser beams and the gases to be detected, either single pass gas channels, multireflection cells or resonant photoacoustic cells are employed. The measuring cells are designed for the lowest possible interference signals and short exchange times.

Precise knowledge of pressure and temperature is required to determine the gas concentration. The sample cell and gas inlet are thus equipped with a uniform temperature stabilization and a pressure control with a fast-reacting valve. The absolute pressure inside the sample cells can be decreased below 100 mbar in order to separate the spectral signature of gas absorption lines.

The detectors used for transmission spectroscopy are typically based on MCT (Mercury Cadmium Telluride). For photoacoustic based measurement systems, we use selected MEMS microphones which are very cost efficient.

Fields of application

Fraunhofer IPM has developed high-end gas emission measurement systems based on fast laser spectroscopy. The systems are customized in close cooperation with industry to various applications:

- Measurements at engine test bed environment for optimization of operation conditions
- Examinations of exhaust gas after-treatment in catalytic converters, in particular simultaneous analysis in front of and behind the converter module
- Measurements of methane slippage emission of block-type thermal power stations
- Designed as an OEM module in process analyzers for monitoring combustion emissions

Technical specifications

Table gases (examples)	CO, CO_2, CH_4, SO_2, NO_x, NH_3, N_2O (depending on laser wavelength)
Continuously heated sampling system	60 to 190 °C (pipes and cell)
Detection limit (gas specific)	ppm down to 1 ppb
Laser wavelength tuning range (MIR)	3 to 11 µm
Measurement rate	5 to 100 Hz
Optical absorption length (sampling cell)	1 to 10 m
Size	Depends on the number of channels, can fit into 19" rack or operate as a standalone unit

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