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FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES IPM

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1 *Laser gas analyzer by Fraunhofer IPM are part of the exhaust gas measurement system for engine test beds, here at AVL LIST GmbH.*
2 *Novel laser-based analyzers technologies like quantum cascade lasers for N_2O can either be integrated into the exhaust measurement system (as 19" rack) or connected to the system as a remote unit.*

CUSTOMIZED EXHAUST GAS MEASUREMENTS

Based on EU legislation, the emission limits for automobiles are lowered continuously. Specific attention is given to greenhouse gases such as carbon oxides, methane and laughing gas. These strict exhaust gas standards require innovative technologies in order to reduce vehicle emissions even further. Optimized drive engineering and exhaust gas management heavily depends on the appropriate measuring technology.

Detection from ppm down to 10 ppb

Fraunhofer IPM has developed a series of spectroscopic analyzer systems particularly designed for measuring exhaust gases. 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 emission peaks and thus tracking of the entire highly dynamic combustion process.

Depending on customer requirements, the systems can be adapted to different tasks. For analyzing fast processes, measurement cycles of up to 200 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. Depending on the relevant gas component, the system can be adapted for higher precisions down to 10 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 interes-

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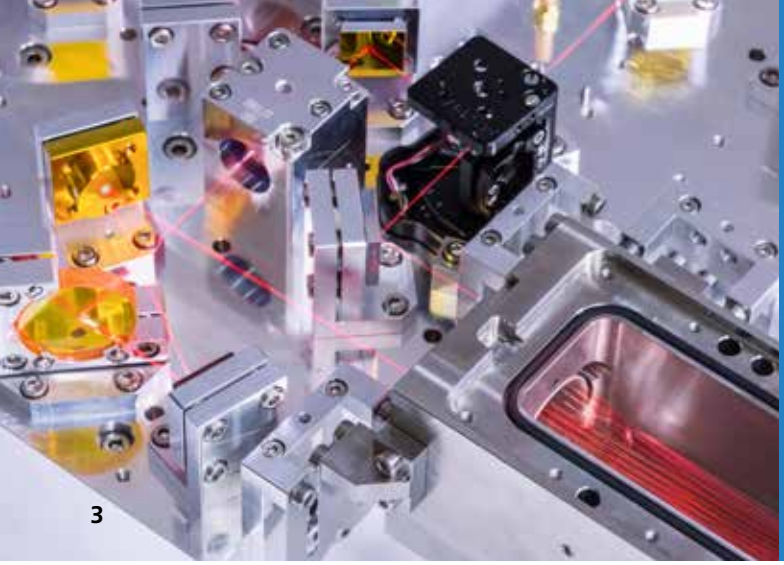

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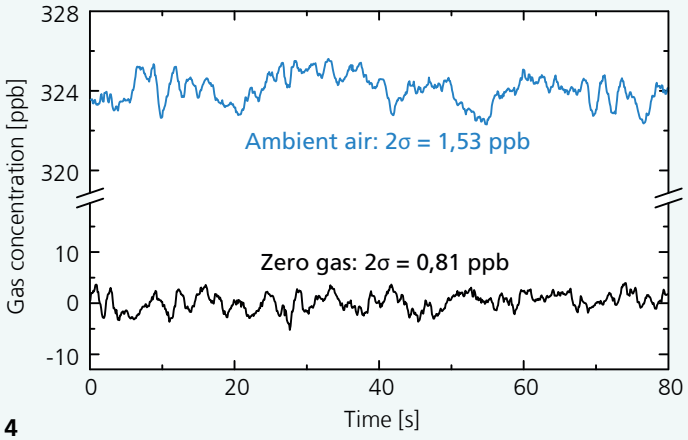

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ting for the simultaneous analysis of varying gas compositions at different positions within the exhaust gas system of a car, e.g. before and behind the catalytic converter module. The focus lies, in particular, on gases like CO, CO_2, CH_4, NO_x, NH_3 and N_2O.

Tunable laser sources, gas sampling and detector technologies

For gas analysis, wavelengths in the mid infrared regime between 4 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. Only a few milliwatts output power is needed for spectroscopic analysis, which can be easily achieved with modern laser devices.
To realize suitable absorption interactions between laser beams and the gases to be detected, either single-pass gas channels or multi-reflection cells, in particular White cells, are employed. White cell feature long interaction paths while at the same time enabling compact devices. Fraunhofer IPM uses White cells with optical path lengths of up to 7.5 m, while the cell itself has a compact design with low volume for fast gas exchange times.

In order to determine gas concentrations from transmission signals, precise knowledge of temperature and pressure is required. The sample cell and gas inlet are thus equipped with a uniform temperature stabilization and a pressure control with a fast reacting valve in combination with a buffer volume. The absolute pressure inside the sample cells can be decreased below 200 mbar in order to separate different gas absorption lines of the exhaust gas matrix and prevent an overlap of different spectral components.

The detectors typically used are based on MCT (Mercury Cadmium Telluride). In stability measurements, the 2σ deviation lies around 1 ppb. This holds for ambient air signal as well as for the zero baseline of pure nitrogen.

3 *Optical setup including a multi-reflection cell. The red laser beam is used for adjustment only.*

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

Fields of application

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

- Measurements at engine test beds environment, determination of various exhaust gas constituents for engine and power train fine tuning under dynamic conditions in order to reduce fuel consumption and pollution emissions
- Examinations of exhaust gas aftertreatment 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

Technical specifications

Detectable gases (examples)	CO, CO_2, CH_4, SO_2, NO_x, NH_3, N_2O up to 4 gas components simultaneously
Continuously heated sampling system	60 to 190 °C (pipes and cell)
Detection limit (gas specific)	ppm to 10 ppb
Laser wavelength tuning range (MIR)	4–11 µm
Measurement rate	5 to 200 Hz
Laser modulation frequency	kHz
Optical absorption length (sampling cell)	1–7.5 m
Size	can fit into 19" rack

All specifications and features are subject to modification without notice.