GRIMM

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Fast Aerosol Particle Emission Spectrometer (FAPES)

The reference system for fast measurements of size distributions

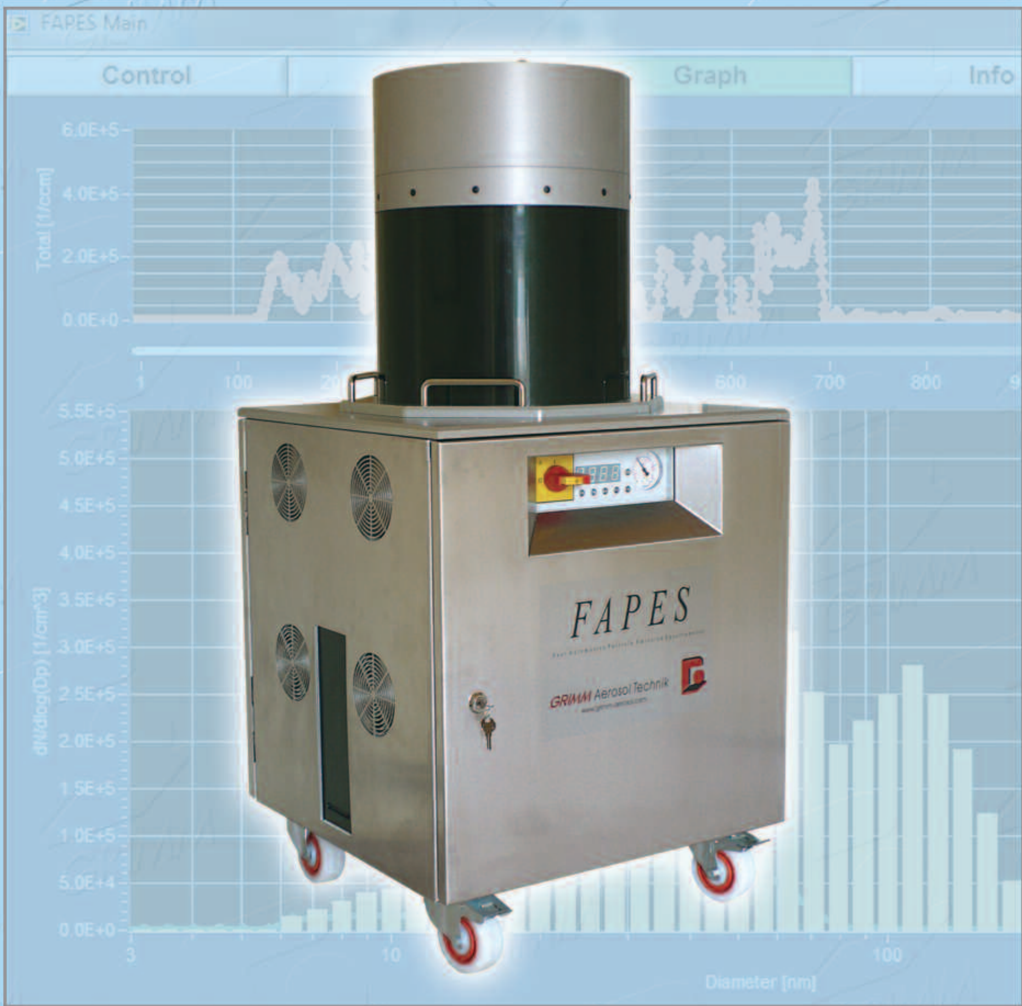
Highlights:

- ✓ Sampling rate up to 10 Hz
- ✓ Size range 6.3 - 474 nm
- ✓ Integrated hot dilution, Neutraliser, and 12 Vienna-type classifiers with Faraday Cup Electrometers
- ✓ Insensitive to soot contamination
- ✓ Tolerates positive and negative pressure
- ✓ Reliable results without calibration
- ✓ Self-tests to assure highest reliability
- ✓ Full size resolution for the range in which other fast instruments fail (>~200 nm)

Applications:

- ✓ Measurements in engine exhaust
- ✓ Combustion studies
- ✓ Monitoring of dynamic processes with nanoparticles
- ✓ Reference system for fast particle sizers

2012

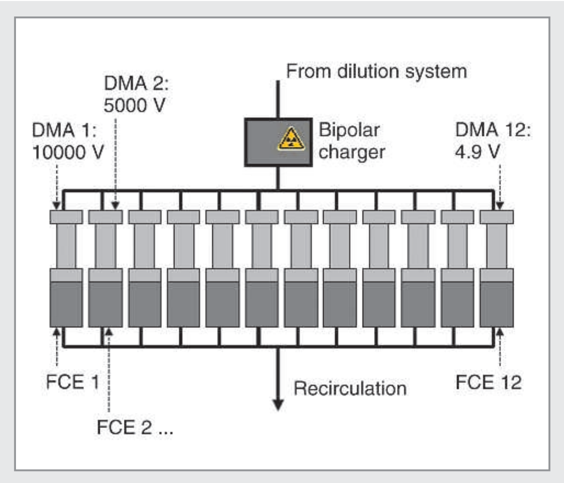


GRIMM has developed a unique system for fast measurements of particles in the size range of 6.3 – 474 nm in a wide range of concentrations (~10^5 to 10^{10} particles/cm^3). The FAPES system includes:

- A well-proven Am-241 aerosol neutraliser for most accurate charging probabilities
- Twelve Differential Mobility Analysers (DMAs) of Vienna-type design, with high size resolution and low particle losses
- Twelve fast and low noise Faraday Cup Electrometers (FCEs), each directly attached to a DMA to minimize diffusion losses
- A fully integrated sampling and dilution system, suitable for temperatures of up to 500°C and for a pressure range of 100 – 2000 hPa
- A control system for air flows using critical nozzles for accurate flow rates at different pressures

Aerosol Analyzer

The FAPES system uses a **bipolar charger** (18.5 MBq Am-241 α-emitter) for establishing a well defined Fuchs-Wiedensohler equilibrium charge distribution on the particles. Moreover, this type of charging results in a high portion of single charged particles in the size range of >~200 nm. Thus, unlike for unipolar chargers, different size fractions feature well distinguishable mobilities even for larger particles. These charging probabilities are the base for a reliable reconstruction of the particle size distribution.



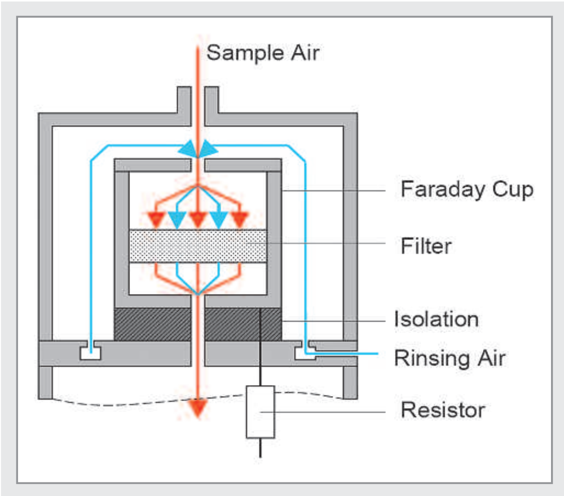
Principle of the FAPES analyser

The charged particles are classified with twelve **Differential Mobility Analysers (DMAs)** operated in parallel. These classifiers are of the well-proven Vienna-type design and feature an active length of 350 mm. Unlike for SMPS systems, each DMA voltage is kept constant and thus the sampling frequency is no longer limited by the scan-time for the DMA voltage. The 12 DMA voltages cover the range of 4.9 – 10000 V and the voltages of adjacent DMAs differ by a factor two to ease the correction of remaining multiple charged particles. The DMAs are operated with a sample flow of 1.6 lpm and a sheath air flow of 8 lpm. This enables simultaneous concentration measurements for 12 size channels in the range of 6.3 – 474 nm. The signal of each size channel originates from an individual DMA and corresponds to a well defined and narrow size range.

Thus the measured size distributions are of excellent accuracy and the FAPES can be considered as the reference for fast particle sizers.

The detection of particles is accomplished with twelve **Faraday Cup Electrometers (FCEs),** one FCE for each DMA. These FCEs feature low noise level (~0.35 fA) and, due to the rinse air, a superior response time of $T_{10\text{-}90}$ = 200 ms. The short response time of the FCE is the base of the fast overall response time of the FAPES ($T_{10\text{-}90}$ = 0.7 s).

The use of rinsing air in the FCE has a second big advantage, namely to prevent contamination on the isolation of the detection electrodes and thus leakage currents. In competitors products, leakage currents between electrodes can degrade the size resolution in the course of the measurements, and the proper cleaning of surfaces is required. Such leakage current can be a major problem particularly for the measurement of engine exhaust because the soot particles are conducting.



Schematic of the FCE detection system

Moreover, the detection of particle charges in the FCE is spatially completely separated from the strong electric fields in the aerosol classifier. Therefore the detected signals are unaffected from any variations of the high voltage, and the FCE signals are insensitive to mechanical shocks and vibration.

Sampling System

The concept of the sampling system is too “freeze” the state of the particles in the exhaust gas and to stabilize their condition for the analysis. This is achieved with a special integrated sample conditioning system with a heated dilution (temperature up to 500°C) right after the sample inlet. The diluter uses recycled sample air to achieve a variable dilution ratio of 1:5.7 – 1:40 in 7 steps. The recycled sample air is filtered, dried, and purified from organic gases with active carbon.

System Description

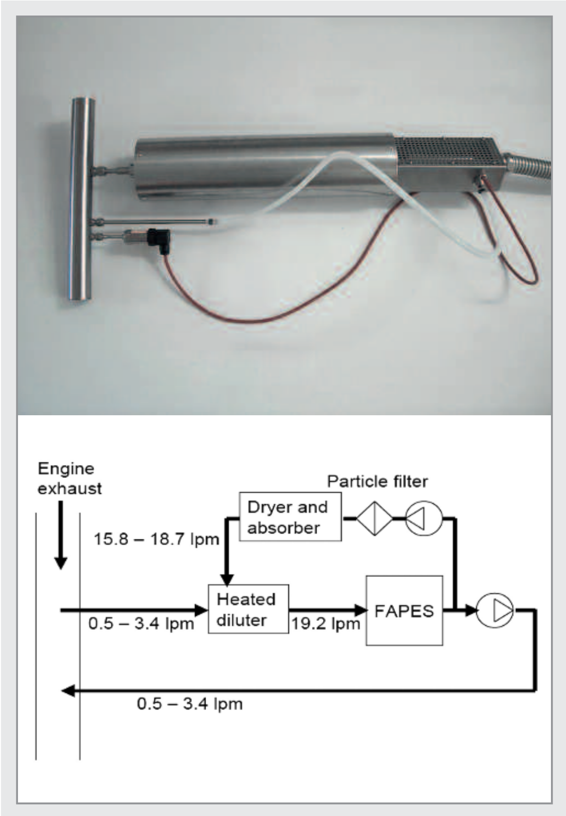


Photo and schematic of the sampling system.

The complete analysing system is at the same pressure as the engine exhaust to avoid any alteration of the state of the particles due to pressure changes. A large range of working pressures (~ 0.1 – 2 bar) is tolerated. The tolerated temperatures and pressures enable the sampling of engine exhaust right after the pre-silencer. It is not necessary to draw the sample from the CVS tunnel, hence the measured size distribution is very close to the actual one in the motor.

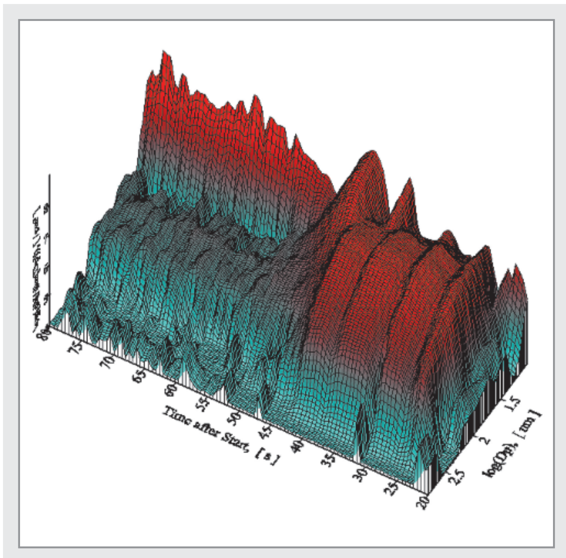
Software

The data inversion algorithm is based on the method of G.P. Reischl (University of Vienna). All calculations can optionally be done with or without common corrections. The results can be shown as raw currents, as number-surface- or mass size distributions. The software shows also time series for various statistical data (total concentration, geometric mean diameter, geometric standard deviation, and others). Different size distributions can easily be compared and the data can be interpolated on a user-selectable grid. Data export is done with a single click. With a separate analog box up to 16 input signals can be monitored, e.g. for triggering the measurements.

Screenshot of the FAPES software

Application Example

The main application of FAPES is measuring the particle size distributions in engine exhaust gas with high time resolution. As particle formation is connected to the fuel combustion process, such investigations can be used to optimize the efficiency of car engines. Moreover, they assist the achievement of compliance with the new EURO5/6 regulations, which include a limit for particle number concentrations emitted by diesel and gas engines.



Example data: Fast Acceleration (0-120 km/h in 20 s) with a diesel engine (1.9 l, EURO3)

The system is, however, also suitable for the fast measurements of size distributions in almost any conditions. Monitoring the size of engineered nanoparticles in airborne state, nucleation events in industrial processes, or measurements in turbine exhaust are just examples.

Specifications

FAPES - Fast Aerosol Particle Emission Spectrometer

The reference system for fast measurements of size distributions.

FAPES	
Sample rate	1, 2, 5 or 10 Hz
Time resolution	$T_{10\text{-}90}$ = 0.7 s
Size range	6.3 – 474 nm at STP (adaptable on request)
Size resolution	12 measured particle sizes, data can be interpolated on a user-selectable grid
Particle concentration range	~ 10^5 to ~10^{10} particles/cm^3
Aerosol charger	Bipolar, 18.5 MBq Am-241 α-emitter
Data filters	Optional, 7 different filters
Operating temperature	5 to 40°C
Operating relative humidity	0 to 100%
Pressure range	100 to 2000 mbar absolute pressure
Communication	RS 232, USB
Inputs	16 signal analog, ± 10 V (adaptable on request, outputs possible)
Dimensions (l × w × h)	600 x 600 x 1250 mm
Weight	250 Kg
Power requirements	2 KW, preferably three-phase current, different voltages are available
Aerosol carrier gas	Air and inert gases

The complete instrument includes the following components:

Faraday Cup Electrometers (12 units)	
Response time	$T_{10\text{-}90}$ = 200 ms
Resistor	1 TΩ
Maximum current	± 3600 fA
Noise	0.35 fA (τ = 0.25 s, 90%), i.e. 52 charges/cm^3 at 1.6 l/min sample flow
Zero point adjustment	Automatic and performed electronically

DMA Classifiers (12 units)	
Active length	350 mm
Diameter of outer electrode	40 mm
Diameter of inner electrode	26 mm
Voltages	4.9 - 10.000 V, positive inner electrode
Sensors (internal)	Temperature, absolute pressure
Sample air flow rate	1.6 lpm, return line to exhaust duct
Sheath air flow rate	8.0 lpm, closed circuit with particle filter and active carbon absorber
Flow control	Critical nozzles

Integrated aerosol conditioning system	
Dilution ratio	1:5.7 to 1:40
Dilution air	Filtered, dried, and purified from organic gases with active carbon
Sampling temperature	5 to 500°C

The European Leader in Particle Measurement Technology

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