New measurement system for PM and ultrafine particles

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1. Introduction

According to a recently published report by the European Environment Agency(1) about one third of Europe's population in cities is exposed to excessive concentrations of particulate matter (PM). These people are also exposed to high concentrations of ultrafine particles caused for example by traffic and heating.
We present a new measurement system that can measure the number concentration and size distribution of airborne particles from 8 nm up to 40 µm. In addition, it also reports simultaneously different PM-fractions such as PM-1, PM-2.5 and PM-10. With a time resolution of 5 minutes it can further capture dynamic changes in the aerosol distribution caused for example by rush hour traffic in the morning and afternoon.

The U-RANGE measurement system combines a scanning mobility particle sizer in which the working fluid to condense the particles can be chosen to be water or butanol with a continuous ambient air quality monitoring system. In the latter a polychromatic light source is used to illuminate aerosol particles as they pass through the optical sensing volume. The scattered light of each individual particle is then detected with a photomultiplier.
The system is operated through a touchscreen with intuitive graphical user interface and integrated data logger. Data can be easily viewed on the screen or later extensively evaluated through the included software.

2. Equipment & principle of measurement

U-SMPS

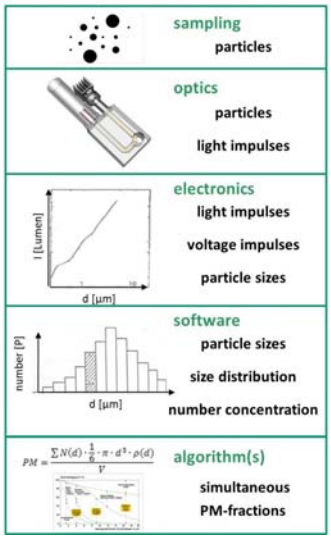
+

Optical aerosol spectrometer

= **U-RANGE**

The U-RANGE is a combination of the Universal Scanning Mobility Particle Sizer (U-SMPS) and an optical aerosol spectrometer (e.g. Fidas®). For ambient measurements this combination additionally reports the mass fractions PM-1, PM-2.5, PM-4, PM-10, and TSP along with the particle size distribution from 8 nm up to 40 µm.

Schematic procedure of the measurement of particle size distribution and PM-fractions with an aerosol spectrometer:



airborne particles of different sizes

optical illustration of a measuring volume as well as the scattered light intensity of a single particle

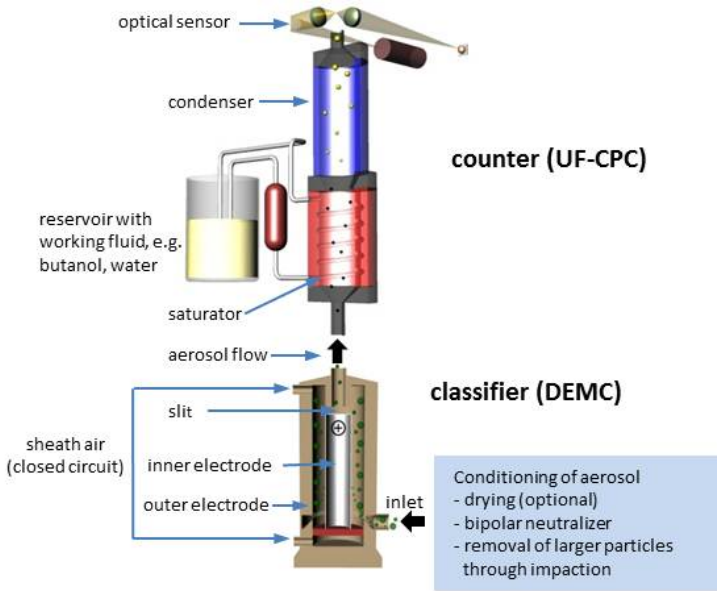
determination of the particle size by allocating the scattered light signal to the particle diameter via an unambiguous calibration curve and measurement of the signal number

classification of the measured particle sizes in size classes in form of a histogram (-> size distribution)

application of a ‚density' and ‚cut off' algorithm to convert the size resolved count data to mass fractions

The ultrafine / nanoparticles are measured using the U-SMPS. A large reservoir for the working fluid allows unattended operation up to one month. The UF-CPC that is used as component of the U-SMPS can be operated with butanol or water and the user can change this at any time.

Working principle of the Universal Scanning Mobility Particle Sizer (U-SMPS)



The Palas® U-SMPS system consists of a classifier (defined in ISO 15900 as Differential Electrical Mobility Classifier – DEMC; also known as Differential Mobility Analyzer – DMA), in which aerosol particles are selected according to their electrical mobility and passed to its exit. During a scan, the voltage in the DEMC is varied continuously, not in steps, which results in higher count statistics per size channel. These particles are then counted by a condensation particle counter (e.g. Palas® UF-CPC).

A well-known and optimized algorithm inverts the measured data to yield the particle size distribution. For the Palas® U-SMPS, Prof. Wiedensohler (IfT Leipzig, Germany) has supplied the algorithm for the SMPS data inversion.

3. Particular advantages & performance of the measurement system

The data of the two principal measurement systems are combined and saved in the internal memory. If connected to a computer or network by one of many interfaces (USB, WiFi, LAN, RS-232/485) data can be easily transmitted (several communication protocols are already supported, new ones will be implemented free of charge) and further analyzed – e.g. through the Palas® analysis software PDAnalyze (figure 2).

The integrated datalogger also enables linear and logarithmic display of measurement values and data management on the device itself (figure 1).

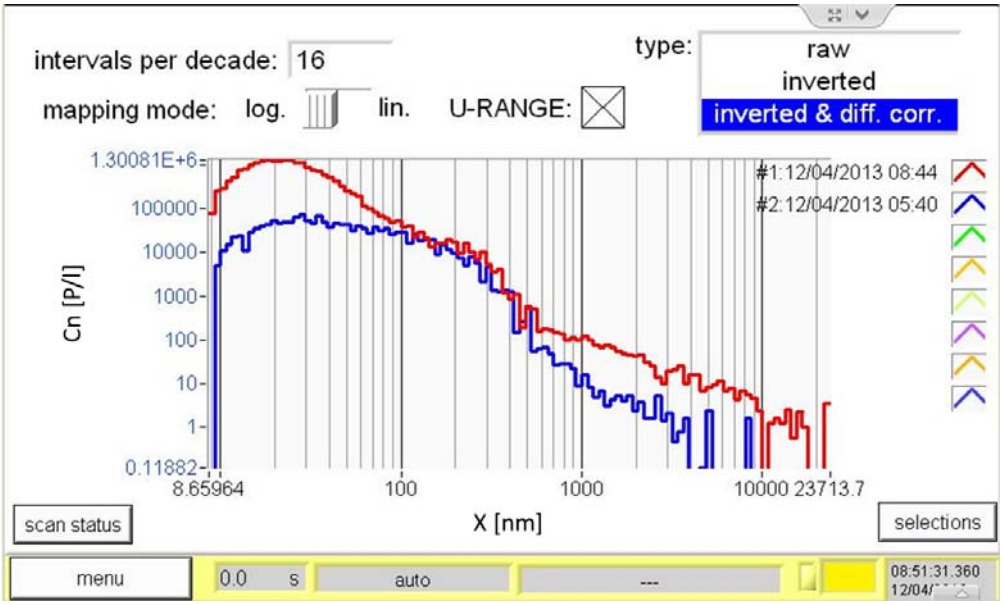


Figure 1: Data display and comparison directly on the touchscreen of the U-RANGE. Blue: indoor aerosol concentration in a production company before shift starts, red: after shift has started.

The data of the U-RANGE are the combined result of a scan with the U-SMPS and the optical light scattering from single particles of the aerosol spectrometer. With the PDAnalyze evaluation software the data can be analyzed separately or combined. Figure 2 shows an example of the combined data of ambient aerosol concentration being evaluated as number concentration (left) or by particle mass (right). The large overlap region (from 180 nm to 800 nm) can be used to deduct further information about the aerosol composition.

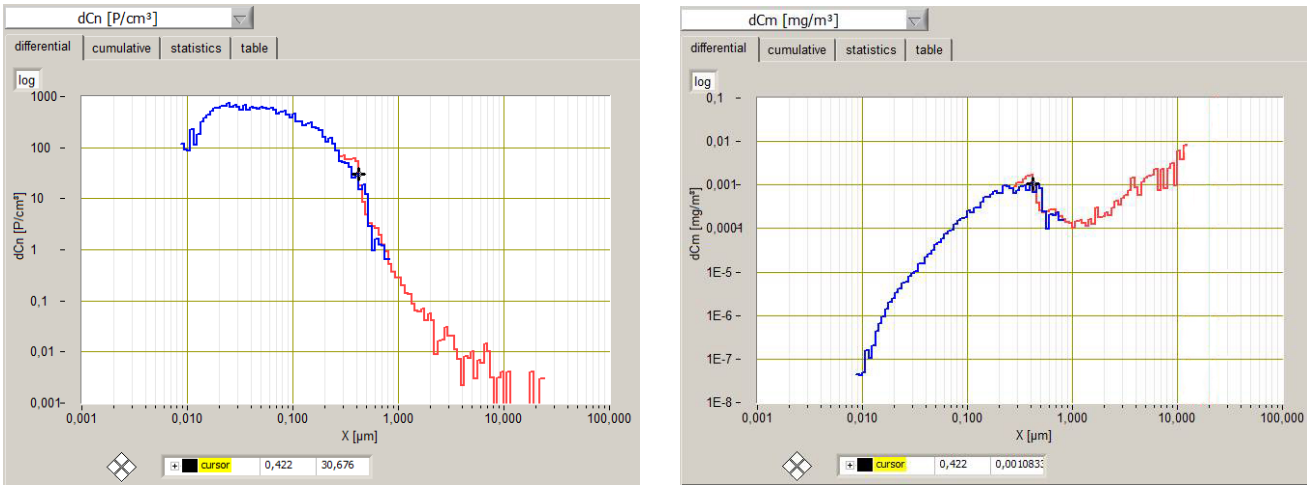


Figure 2: Ambient aerosol concentration measured with the U-RANGE. Left: number concentration, right: mass concentration. Blue: U-SMPS scan, red: data from the Fidas®.

4. Summary & conclusions

The Palas® U-RANGE measures the airborne particle concentrations in the size range of 8 nm up to 40 µm. By this measurement of the whole inhalable size range it can be differentiated which particles actually contribute to pollution (smaller particles penetrate deep into the human respiratory tract but often don't contribute to PM-fractions). With a time resolution of 5 minutes daily dynamics (e.g. morning and evening rush hours, construction sites) are visualized.

This can be important information for risk assessments and modeling.

The new Palas® U-RANGE for the time- & size resolved measurement of airborne particles has been presented. It is designed to monitor and provide data to analyze air quality:

- in specific traffic zones (e.g. „Umweltzonen" in cities in Germany)
- in the ambient environment (including cities and industrial areas)
- at workplaces to determine concentration levels and effectiveness of protective measures

5. Literatur

(1) http://www.eea.europa.eu/de/pressroom/newsreleases/viele-europaer-sind-weiterhin-luftschadstoffen-ausgesetzt

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Jürgen Spielvogel, Maximilian Weiß, Leander Mölter
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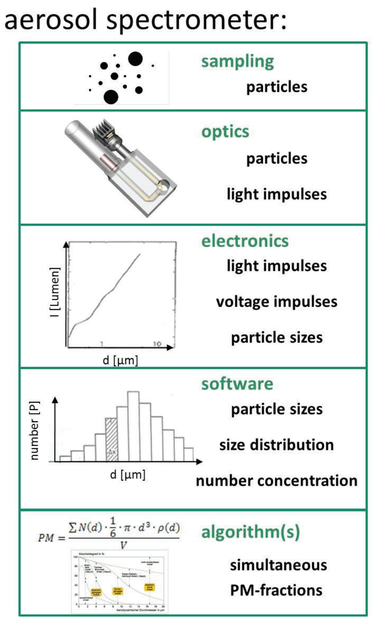

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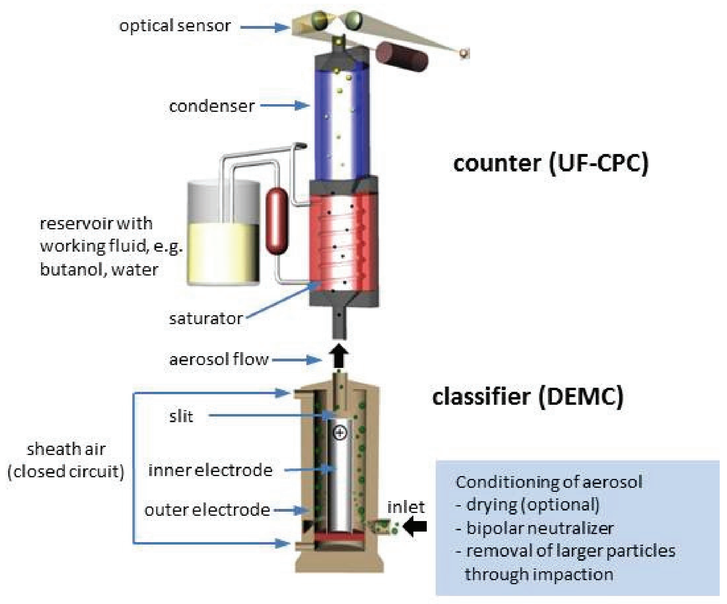

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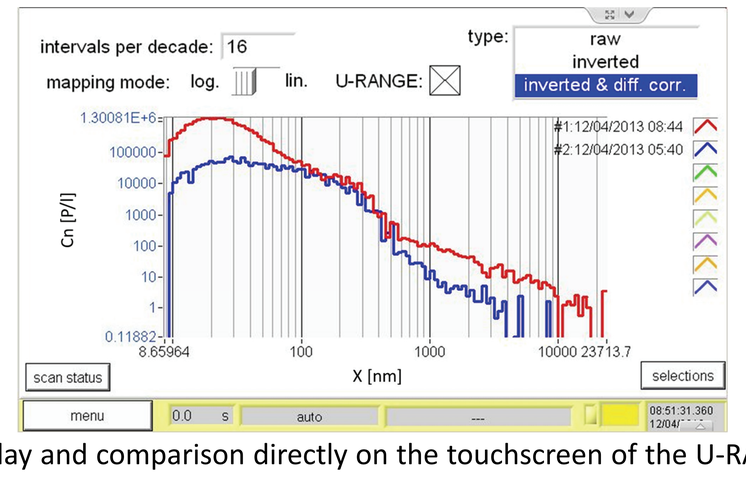

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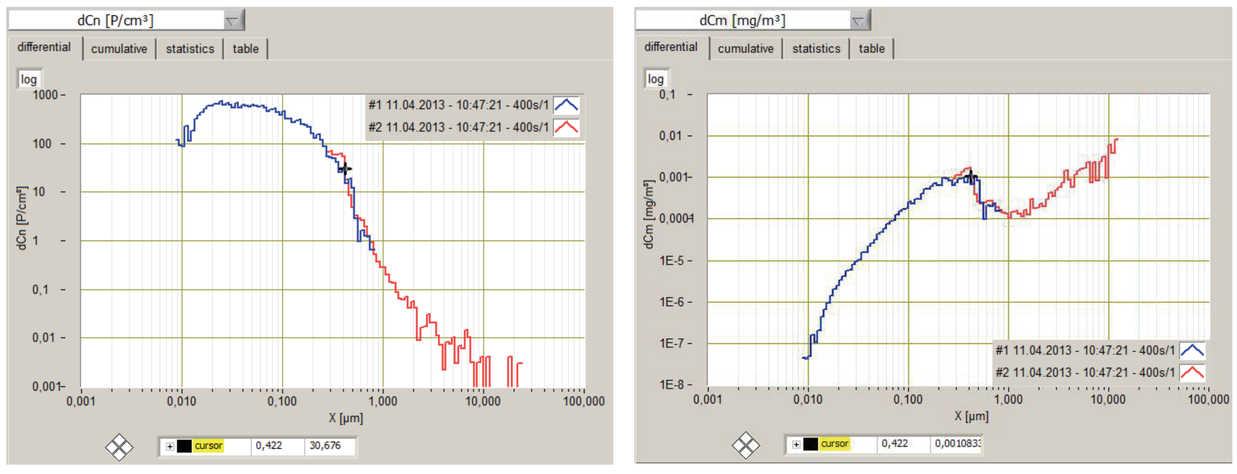

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