“Performance of a new commercial electrical mobility spectrometer”

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INTRODUCTION

Electrical mobility spectrometers (EMS) like the SMPS or DMPS are the most often used instruments for measuring particle size distribution in the submicron particle size range. As measurements in this size range become increasingly important for ambient and technical aerosols, reliable and affordable instruments are required. A typical EMS consists of a DMA (Differential Mobility Analyzer) to classify particles due to their size and charge into mobility fractions, which are then counted by a counter like a CPC (Condensation Particle Counter) or a FCE (Faraday Cup Electrometer). The performance of such a system depends on the performance of these two elements like the size dependent counting efficiency and the step response characteristic of the counter and the transfer function of the DMA. Here the performance of the new EMS system of the company Grimm, consisting of a long classifier (ESC 5.4-300) and a condensation particle counter (UPC 5.403) was tested.

COUNTING EFFICIENCY

For the determination of the counting efficiency, a hot wire Wo_x generator was used, to generate a tungsten oxide aerosol in the size range between 1 and 15 nm (Reischl, 1997). The aerosol was then charged in a radioactive source of high activity and then classified in a very short Vienna type DMA, with an effective length of 1.4 cm and an aerosol to sheath air ratio of Q_a = 2 lpm to Q_{Sh} = 25 lpm. To determine the counting efficiency of the UPC 5.403, a FCE was used as a reference counter. A three parametric exponential fit (Mertes, 1995) was applied to the measured data and a Cut Off Diameter (50 % counting efficiency) of about 4.5 nm was determined, which is a good result compared to other commercial CPC.

STEP RESPONSE

To measure the response of the CPC to a concentration step at the aerosol inlet, a three way valve was used, to switch between filtered air and ambient air. As could be seen by the measured data, the response of the instrument shows the ideal behaviour of a straight line on a logarithmic scale for the first seconds, but for longer times a deviation could be observed. This can be described by a superposition of a second exponential decay, which can be caused by non ideal flow phenomena like eddies or dead volumes inside the instrument.

TRANSFER FUNCTION MEASUREMENT

For the measurement of the transfer function, a NaCl aerosol was generated with an atomizer and a diffusion dryer. The aerosol was then charged and classified in a first DMA (Hauke 3/150) using a fixed voltage for each measurement. The monomobile distribution was then scanned over with the second DMA (Grimm ESC 5.4-300). Behind each DMA, the concentration was measured using two CPCs, so that the relative count rate could be determined. The influence of diffusional loss in the tubing to both counters was considered by measuring a relative counting efficiency of the two CPCs.

In addition to the measurements, simulations based on the transfer function described by Stolzenburg were performed (Reischl, 1997), by using the known characteristic of the Hauke DMA and assuming the ideal transfer function for the Grimm DMA. This simulation took into account only the diffusional loss and broadening inside the classifying zone of the DMA, but not the loss in the aerosol inlet and outlet of the classifier. For this reason a deviation between the experimental points and the prediction of the simulation, which is caused by loss in the inlet and outlet of the classifier, could be observed. Therefore the measured relative counts were normalized to the height of the peak of the simulation, so that the data could be compared. For a particle size of about 100 nm, the transfer function of the second DMA seems to be a bit broader than the ideal function, which was assumed in the simulation, however the deviation is minor.

The comparison for different particle sizes between normalized measurements and the simulations shows an interesting effect. It seems, that for smaller particle sizes the transfer function becomes narrower – but this is only an effect of the normalization, that is based on the assumption of a size independent particle loss. For higher relative electrical mobilities, which means smaller particles (single charged), the loss is higher than expected and therefore the measurements seem to be better than the simulations. For future work it is planed, to take into account the diffusional loss in the aerosol inlet and outlet, so that a better match between the measurement and the prediction of the simulation could be achieved.

SUMMARY

The performance of a new CPC (Grimm UPC 5.403) and a new DMA (Grimm ESC 5.4-300) was examined. The size dependent counting efficiency of the counter was measured, and the Cut Off Diameter was determined to be about 4.5 nm. Also the step response of the CPC was measured and a non ideal behaviour was observed for longer times, which could be caused by non ideal flow phenomena inside the instrument. Finally the transfer function of the DMA was measured and the results were compared to numerical simulations. As the simulation did not take into account particle loss in the aerosol inlet and outlet of the classifier, it was necessary to normalize the measurement data. By this comparison it could be seen, that the transfer function of the Grimm DMA is a bit broader than the ideal transfer function – however the deviation is minor.

References

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Mertes S., Schröder F., Wiedensohler A. (1995) The Particle Detection Efficiency of the TSI-3010 CPC as Function of the Temperature Difference between Saturator and Condenser, Aerosol Sci. Technol. **23**, 257 - 261

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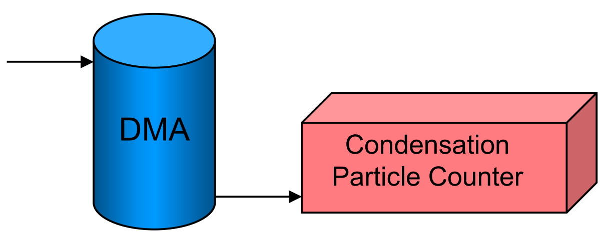
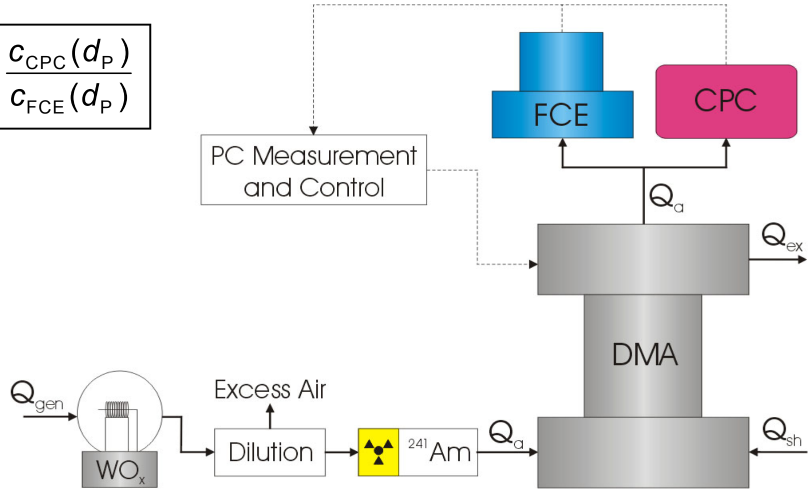
Performance



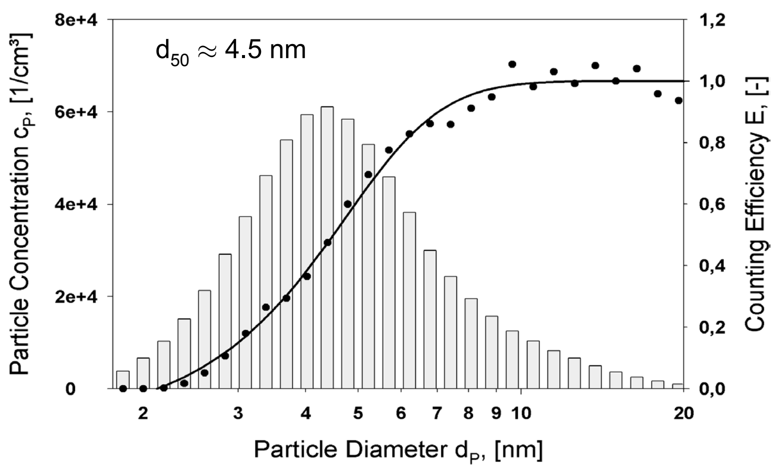
- Particle size dependent counting efficiency of the CPC
- Time response characteristic of the counter
- Transfer function of the DMA

Method: Counting Efficiency

$$E(d_P) = \frac{c_{CPC}(d_P)}{c_{FCE}(d_P)}$$

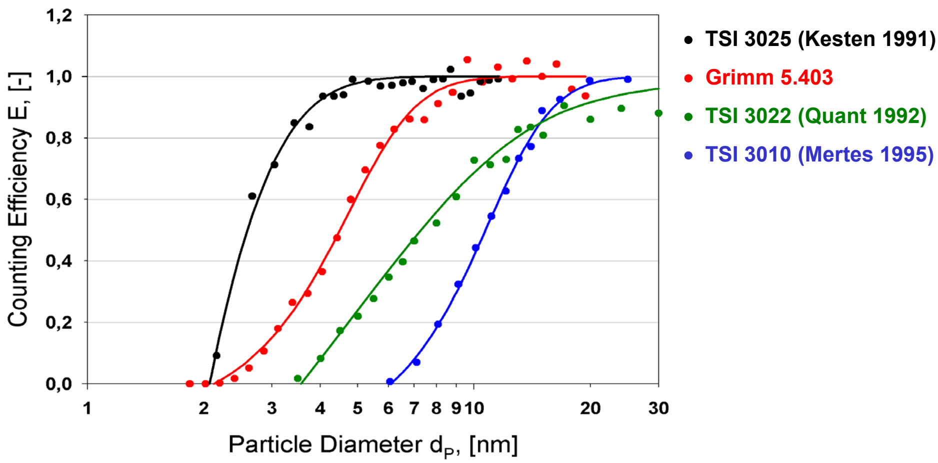


Results: Counting efficiency



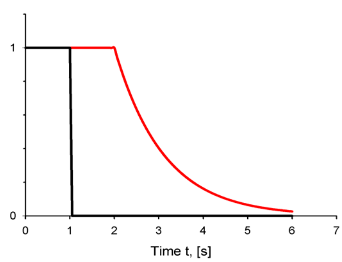
counting efficiency – response function – transfer function

Comparison: Counting Efficiency



counting efficiency – response function – transfer function

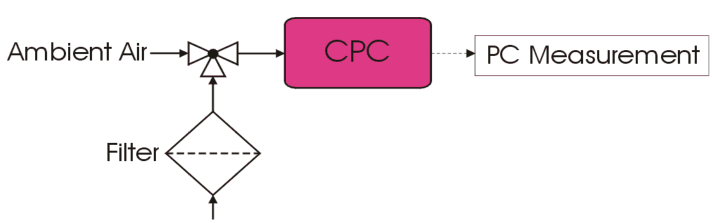
Method: Step Response



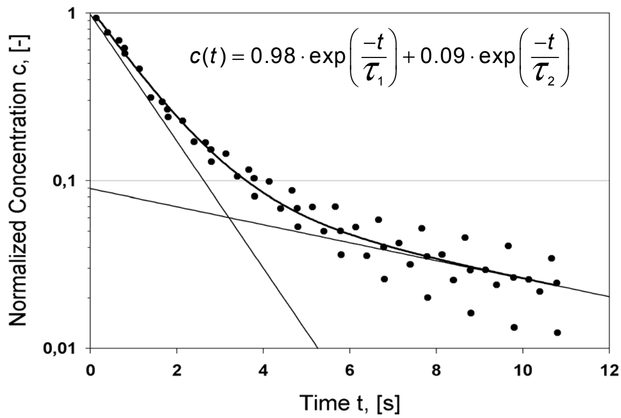
Ideal step response:

a) dead time element

b) first-order time-delay element (exp. decay)



Results: Step Response



- Non-ideal response
- Superposition of two exponential decays

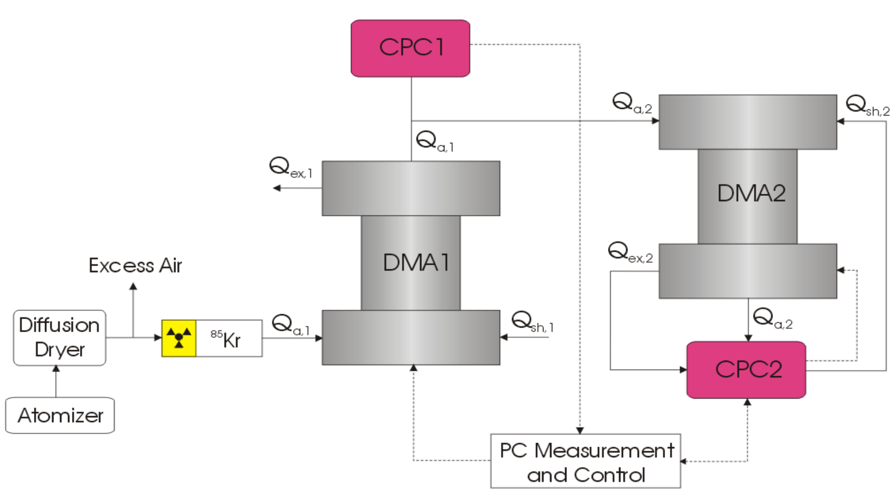
$\tau_1 = 1.15$ s

$\tau_2 = 8.1$ s

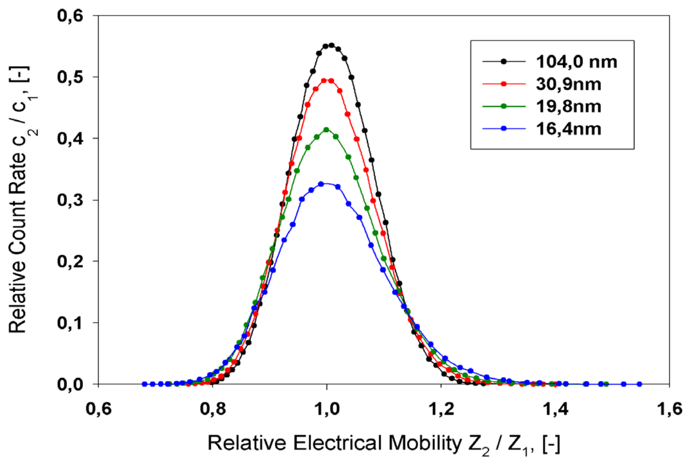
Second term caused by flow disturbances:

eddies, dead spaces

Method: Transfer Function

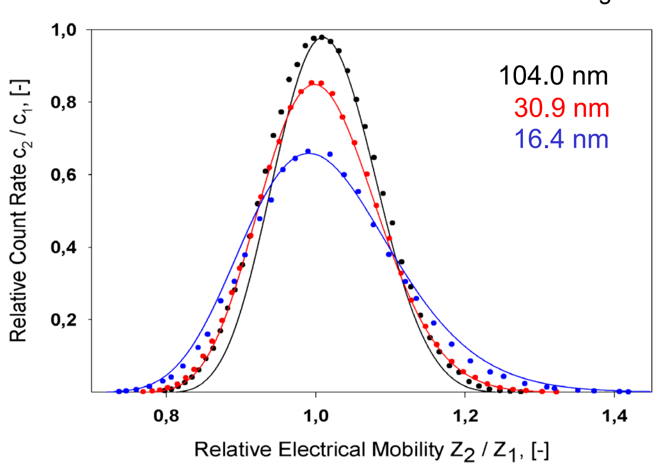


Results 1: Transfer Function



Results 2: Transfer Function

• Numerical Simulation with correction for diffusional broadening and loss



Summary

- Counting efficiency of the Grimm 5.403 CPC was determined. Cut off diameter is 4.5 nm which is a good performance compared to other instruments.
- Time response of the CPC was measured. A second characteristic time was found, which could be caused by non-ideal flow inside the instrument.
- The transfer function of the Grimm DMA was measured and compared to numerical simulations – a good agreement was found. For future work planed to expand the simulation to take into account diffusional loss in the aerosol inlet and outlet of the DMA.