A portable Diffusion Size Classifier

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Motivation

- The current generation of particle measurement instruments is large, heavy and expensive (for example SMPS, ELPI, EEPS, DMS).
- Portable instruments exist: CPCs, personal samplers, optical instruments, DC/PAS – however, none of these gives nanoparticle size and number information online.
Diffusion charging (DC) principle

Particles are charged, then trapped in a filter. The current flowing from the filter is measured – a very simple instrument.
Typically, the average charge carried by a particle of diameter $d$ after diffusion charging is well described by a power law

$$q \sim d^b$$

The exponent $b$ is usually in the range of $1.1...1.6$

A diffusion charger measures something like „total aerosol length“ (small $b$) or „total active surface“ (large $b$). It gives no information on the particle size!
Improving the simple DC

Diagram showing the components: Inlet, Charger, Ion trap, Filter, Electrometer, To pump, HV.
Improving the simple DC

Inlet       Charger      Ion trap

Filter

Electrometer

Inlet  Charger  Ion trap

Filter   To pump

HV
Add a diffusion stage which consists of a stack of grids in front of the filter:
The diffusion stage

- Small particles are deposited preferentially in the diffusion stage (since they have a high diffusion coefficient and move about a lot)
- Large particles are deposited preferentially in the filter stage
- The ratio of the filter stage current F divided by the diffusion stage current D is related to the particle size
- Calibration with monodisperse Aerosol:
Size determination with F/D

F/D is well approximated by a linear function in the size range from 20...150nm
Number Concentration N

- Diameter is determined via F/D
- Total current measured is

\[ j = F+D \sim N \ q(d) = N \ c \ d^b \]

- \( \Rightarrow \) N can be determined from total current and charger characteristics:

\[ N \sim (F+D)/(d^b) \]

- \( \Rightarrow \) measuring two currents, you get N+d!?
Polydisperse Aerosol – a Problem?

- Calibration with monodisperse aerosol
- In polydisperse aerosol, larger particles carry more charge and contribute more to the measured currents
- => The measured F/D overestimates the diameter
- => The calculated number turns out too low
- However, for a known size distribution, correction factors can be applied
- Correction factors are „small“, i.e. 20-30% for a lognormal size distribution with $\sigma = 1.7$
Example Implementation

- Battery powered (12h)
- Size: 2 laptop computers
- Weight: 5.5 kg
- Transmits data via Bluetooth to PDA or PC
- Potentially smaller & lighter
# Laboratory Results

<table>
<thead>
<tr>
<th></th>
<th>SMPS d</th>
<th>DiSC d</th>
<th>SMPS N</th>
<th>DiSC N</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>47.6</td>
<td>51.9</td>
<td>3.4E5</td>
<td>3.0E5</td>
</tr>
<tr>
<td>WOx</td>
<td>15.6</td>
<td>17.4</td>
<td>3.7E5</td>
<td>3.3E5</td>
</tr>
<tr>
<td>CAST 1</td>
<td>24.3</td>
<td>23.1</td>
<td>2.7E5</td>
<td>2.3E5</td>
</tr>
<tr>
<td>CAST 2</td>
<td>47.8</td>
<td>45.5</td>
<td>3.0E5</td>
<td>2.7E5</td>
</tr>
<tr>
<td>CAST 3</td>
<td>86.1</td>
<td>77.6</td>
<td>4.1E5</td>
<td>3.7E5</td>
</tr>
</tbody>
</table>

Too good to be true?
Bimodal Aerosol - a Problem!

- Results on last slide: for aerosol with $\sigma = 1.7$
- For bimodal aerosol larger errors occur
- Example: with $\sigma = 2.2$, diameter is 40% too large
DiSC performance summary

- Number concentration and average diameter measurement with an accuracy of ~30% (but can be worse in case of very broad size distributions)
- Fast time response (~2s)
- Detection limits: from $10^3$ to $10^6$ pt/ccm; upper limit depends on particle size
Applications

Mobile Lab:
U of M:   PSI:   FHA:
Applications (seriously)

- Any type of measurement which doesn’t have to be very accurate like...
- Workplace pollution monitoring
- Mobile measurements & personal monitoring
- Regular DPF testing (good/not good)
- Process monitoring (Stability of an aerosol source, for example)
Conclusions

- DiSC is a very simple device
- DiSC measures size and number with reasonable accuracy
- DiSC is ideal for applications with low accuracy and high mobility requirements
- DC signal (F+D) is also available
Yesterday, late at night:
Yesterday, late at night:
Martin's uncertainty principle for aerosols:

- The more precise your measurement is, the less relevant it gets!