Development of a primary standard for particle number concentration

Molzahn M.[1], Goetz M.[1], Krause C.[2], Drung D.[2]; Nowak A.[1]

[1] Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany
[2] Physikalisch-Technische Bundesanstalt (PTB), Abbestr. 2-12, 10587 Berlin, Germany
Corresponding author: markus.molzahn@ptb.de

Background:
Currently, the primary standard used at PTB for a metrological calibration of particle counters is a commercially available device. In this abstract, we are presenting the development of a manufacturer-independent method for the measurements of particle number concentration. The independency is a necessary step to better understand the measured raw values for establishing a robust pathway of traceability to the SI unit Ampere. For this purpose, a Faraday Cup Aerosol Electrometer (FCAE) [1] is used together with an Ultrastable Low-Noise Current Amplifier (ULCA) [2] for the measuring current to convert it into a measurable voltage scale.

Methods:
To identify the signal to noise ratio (SNR) of the system, all individual components were measured without input signal (baseline check) and the Allan variance [3] was calculated for several lab studies. The influence of vibration was investigated and reduced by a provisional vibration decoupling. Furthermore, the previous standard coaxial cable connecting the FCAE and the ULCA was replaced by a low-noise type. Finally, an intercomparison study was conducted with two commercially available FCAEs, which are typically used for international key comparisons of National Metrology Institutes [4]. Therefore, the SNR and the consistency of the results (EN score) were determined, and a moving average was used to visualize the correlation between the measured values.

Results:
The first version of our primary standard shows good agreement with the results of commercially available FCAEs. The SNR for a particle concentration of 5500/cm³ is about 20 dB, while the SNR of commercially available FCAEs is about 30 dB. The calculated correlation coefficient is about 0.84 and higher. Regarding SNR, there is room for further improvement because the system still reacts sensitively against vibrations, which are mostly caused by other devices running in the laboratory. The dominant noise source during the measurement is the FCAE itself in its current state.

Conclusion and further goals:
The aim of this work was to optimize the system for improved counting efficiency of airborne nanoparticles below 20 nm over a wide range of particle number concentration. In this range, the measured current lies between 8 fA for 1000 charged particles/cm³ and 400 fA for 50,000 charged particles/cm³ at a volume flow of 3 l/min. Future strategies are aiming to detect even smaller particle sizes and lower particle number concentrations.
For precise measurement with the new primary standard at PTB, especially in the current range below 8 fA, further investigation and modification are necessary. First, a better vibration decoupling of the system is essential, therefore the housing of the system must be optimized. Second, shorter low-noise cables can also minimize interfering effects caused by vibration. Additionally, a new housing offers the possibility of using technologies such as Peltier elements to reduce temperature effects.
However, to measure small quantities of charges with a Faraday cup pushes this technology to its limits. [5] We assume that the movement of the electrons within the system can cause interactions that degrade the SNR. A more compact design and new materials may reduce this interference.

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