A new visual expansion-type Condensation Particle Counter

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The particle number concentration is an important fundamental property of aerosol populations and is usually measured with Condensation Particle Counters (CPC). In these instruments nanometer-sized particles are magnified by condensational growth to sizes detectable by light within the range of the visual spectrum. This concept is applied in various commercial and custom-made setups (see McMurry, 2000, and references therein).

One approach for achieving the required super-saturation is realized in "expansion-type" CPCs through fast adiabatic expansion. Different methods have been applied for retrieving the number concentration of the particles after their activation and growth to micrometer-sized droplets. These automated methods usually rely either on the measurement of scattered or transmitted laser light after interaction with the droplet population (e.g. Kürten, 2005). Especially the reliable detection of low particle concentrations with such measurements can, however, be challenging because of noise or drifts in the measured light intensity.

We have developed a new expansion-type particle counter based on the visual detection of individual droplets. The design of the VIPER (Visual expansion-type Particle counter) utilizes a CCD camera and a fully automated image analysis based on a LabVIEW program. A section of the expansion chamber is illuminated by laser light. The laser beam is "shaped" by a cylindrical lens and defines – together with the chamber geometry – a thin optical volume which is used for the particle detection. A series of digital images is taken shortly after the adiabatic expansion and subsequently processed afterwards. The particles visible in the illuminated volume are counted autonomously by image analysis software.

This direct method of observation offers an absolute measurement of individual aerosol particles and is no longer dependent on the interpretation of intensity measurements. As single particles are individually detected rather than the optical properties of a particle ensemble, the result is basically unambiguous. Thus, the method can in principle be independent of calibration. However, the correct geometry of the illuminated volume and the loss of particles due to the expansion have to be taken into account.

The experimental setup of the VIPER is demonstrated to have a reliable performance under various experimental conditions in the laboratory and in the field. The particle size at which 50% of the particles are detected has been determined to be D_{p50} = 8nm (cut-off diameter) with detection of particles beginning at 3nm (using water as the working fluid).

The maximum concentration which can be measured accurately is around 4.4×10^5 cm^{-3}. The lowest measurable concentration is constrained by the counting statistics due to the rather small optical volume. Given this constraint a concentration of 2000 cm^{-3} would be measured with a statistical error of approx. 10 %.

The super-saturation achieved inside the measurement chamber can be controlled by the expansion ratio. Therefore, a thermal conditioning is not required which helps to keep the set-up simple. In addition to that, controlling the expansion ratio has further important advantages: (1) The super-saturation can quickly be adjusted between different expansions to set different lower cut-off sizes in subsequent measurements without time delay. (2) The whole setup can be made isothermal. This would allow the application of VIPER in low temperature environments. Thereby, the potential risk of evaporating particles before the measurement can be avoided.

Detailed instrument characterizations will be presented as well as side-by-side comparisons with other particle counters. We discuss the assessment of different working fluids and the performance of the VIPER CPC during field experiments.

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