High-resolution low-pressure cascade impactor

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Keywords: cascade impactor, aerodynamic size

Probably the most important characteristic of nanoaerosol is the particle size distribution. Particle size defines in large extent the behaviour of an aerosol particle in many processes, such as transportation, aerosol dynamics, particle charging, etc. Thus, the measurement of particle size is one of the key aspects in nanoparticle research. In nanoparticle synthesis, emission characterization, and atmospheric research focus is in the particle size range of below 100 nm, and often the phenomena are highly transient (e.g. Karjalainen et al., 2014). This drives the need for high-end measurement devices that operate in real-time and in nanoparticle size range.

There are only a few instruments that are capable to measure below 100 nm particle size in real-time (excluding integral quantities measuring instruments): Electrical Low Pressure Impactor (ELPI, Keskinen et al., 1992) and Engine Exhaust Particle Sizer (EEPS, TSI Inc.) ELPI measures aerodynamic size distribution using the electrical detection of particles with a cascade impactor, and has 12 channels in the measurement range of 16 – 10000 nm, and below 100 nm, 4 channels. EEPS measures electrical mobility size distribution using electrical detection of particles and has 22 current measurement channels in the size range of 6–560 nm. ELPI has coarse resolution under 100 nm compared to EEPS, limiting its applicability in nanoparticle studies.

In this study, we present a new high-resolution low-pressure cascade impactor (HRLPI, Arffman et al., 2014) that has 10 impactor stages in the size range of 7.7–142 nm and a filter stage. The HRLPI impactor operates at 40 mbar pressure with the sample flow rate of 1.1 lpm. The HRLPI was fitted to the ELPI body, and a small self-made corona charger was used before the impactor to produce a known charge distribution for particles. HRLPI uses a separate pressure reduction inlet to bring the aerosol from the ambient pressure to the impactor inlet pressure. The essential feature in the HRLPI is to use slit type, short throat length nozzles in the impactor stages. The nozzles of this type have been shown to produce very steep collection efficiency curve shape (Arffman et al., 2012). Sharp cut-curve shape allows doubling the number of measurement channels below 100 nm compared to ELPI impactor without significant overlap of kernels. The minimal overlap of the kernels makes the inversion or interpretation of the measurement results simple and robust, as the cut-point concept works well with HRLPI. All the impactor stages, charger and inlet were fully calibrated with monodisperse dioctylsebacate (DOS) particles produced by SCAR instrument (Yli-Ojanperä, 2010) and an evaporation-condensation method.

In the laboratory, the performance of HRLPI was compared to ELPI+, ELPI with improved nanoparticle resolution (EELPI), EEPS, and two SMPSs (DMA models TSI 3071 and TSI 3085). The instrument was also tested in the field measurements, where the diesel exhaust of a modern passenger car engine was characterized with HRLPI, EELPI and EEPS in parallel. Figure 1 shows an example of the test measurement results.

![Figure 1. Particle size distribution measured with different instruments for externally mixed DOS and NaCl aerosol.](image)

Results of the test measurements showed that HRLPI is a well-suited aerodynamic size measurement instrument for the cases where the interesting size range is approximately 5–200 nm. Compared to the other low-pressure impactors, it has a better size resolution and the lowest cut point. By combining the mobility and aerodynamic particle size distribution measurements of EEPS and HRLPI, the effective density of the particles down to at least 7 nm can be determined in real time.