LAPAZ - a laser particle counter as a primary number concentration standard

J. SCHLATTER

Swiss Federal Office of Metrology and Accreditation, 3003 Bern-Wabern, Switzerland

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INTRODUCTION

Calibration of nanoparticle characteristics is an oncoming issue due to legal applications. Several projects aim at emission limits for exhaust gases from diesel vehicles. International standards for clean rooms define particle concentration limits for several size classes. Standards for particle sizes in aerosols are commercially available as suspensions of latex spheres. They come with a certificate in order to prove the traceability to SI-units. But for particle number concentration, the traceability is missing (Schlatter, 2000). Some effort has been achieved with the inter-comparison of different types of condensation particle counters CPC (Dahman et al, 2001, Wiedensohler et al, 1997) and electrometers (Wiedensohler et al, 1990). METAS has established a primary standard based on counting directly the pulses of light scattered by single particles.

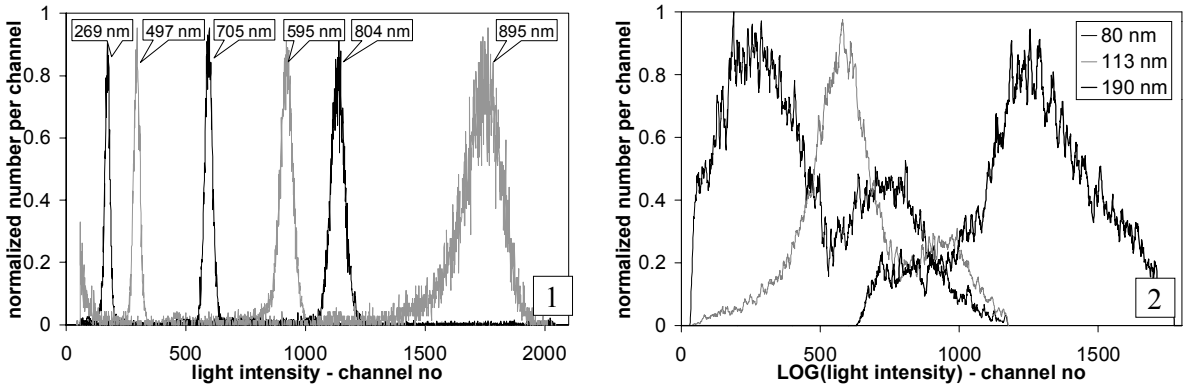
CONCEPT

The LAPAZ (LAser PArtikelZähler) uses the principle of light-scattering by small particles. Since the intensity of the scattered light depends on the wavelength, particle size and the angle of observation, there are a number of possible configurations. A limiting factor is the particle size for diameters larger than about 100 nm, due to the fact that intensity of scattered light increases with the sixth power of the particle diameter (Rayleigh scattering). Combining adjustable high intensity laser light with powerful optics and a very sensitive and fast detector enables LAPAZ to detect and count single particles below 100 nm. Short tubes at the entrance of the measuring cell minimise losses due to diffusion.
The LAPAZ consists of four components: a laser, measuring cell, receiver optics, and data collection. The solid state green laser (Coherent VERDI V5) delivers light with a wavelength of 532 nm and at 5 W power. The beam is collimated to a diameter of 0.7 mm. The aerosol jet has a diameter of 0.1 mm and flows through the measuring cell at a rate of 17 ml/min. It intersects the laser beam perpendicular. The receiver optics detects the scattered light perpendicular to both laser beam and aerosol jet. It covers a solid angle of 45°. Each passage of a particle through the laser beam produces a scattered light pulse of 3 µs duration. The signal's peak from the photomultiplier feeds to a multi-channel analyser (Tracor Northern: TN-7200) with 2048 channels. The particles are counted during a typical measuring period of 500 s.

MEASUREMENT CAPABILITY

LAPAZ detects latex particles between 100 and 900 nm (Figure 1) and combustion particles with a mobility diameter of 100 nm to 200 nm (Figure 2).
The latex particles produce pulse intensity as a function of particle size. If the diameter exceeds 100 nm the Mie-Theory describes the scattering of light. This calculation predicts that the intensity does not increase uniformly with particle size. For example the intensity for particles with a diameter of 700 nm is lower than for 600 nm. But the range of intensities for monodisperse particles is narrow and allows a reliable

detection. Concentrations of latex particles can be measured with an uncertainty of 10 % (95 % probability).
First tests with combustion particles from the Combustion Aerosol Standard CAST (Jing, 2000) show much lower intensities and much broader intensity distributions. Nevertheless the sizes (as electrical mobility diameter) can be distinguished. The particle concentration is calculated from the area under the curve and the aerosol flow rate. The concentration is consistent with a measurement of the CPC within 20 %.
The advantage of LAPAZ is its simple concept. Therefore there are only a few parameters influencing the uncertainty. The main parameters are the aerosol flow and the noise in counting.



Figures 1 and 2. Measurement of latex particles (a) and combustion particles (b) from CAST

CONCLUSION

The new instrument LAPAZ can be considered a primary standard for counting latex particles in the range from 100 nm to 900 nm diameter and concentrations up to 1000 cm^{-3}. LAPAZ allows the calibration of particle counters with an improved uncertainty and using a completely different measuring technique. This enhances the acceptance of particle counters in legal applications.

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REFERENCES

Dahmann, D., Riediger, G., Schlatter, J., Wiedensohler, A., Carli, S., Graff, A., Grosser, M., Hojgr, M., Horn, H.-G., Jing, L., Matter, U., Monz, C., Mosimann, T., Stein, H., Wehner, B., Wieser, U. (2001). Intercomparison of mobility particle sizers (MPS), *Gefahrstoffe - Reinhaltung der Luft,* 61, 423-428

Jing, L (2000), Properties of soot particles produced by a combustion aerosol standard, in *Fourth International Workshop on Nanoparticle Measurement*, 25

Schlatter, J (2000), Legal Aspects of Particle Measurements, in *Fourth International Workshop on Nanoparticle Measurement*, 28

Wiedensohler, A., Hansson, H.-C., Keady, P.B., Caldow, R. (1990). Experimental verification of the particle detection efficiency of TSI 3025 UCPC, *J. Aerosol Science*, 21, S617-S620.

Wiedensohler, A., Orsini, D., Couvert, D.S., Coffmann, D., Cantrell, W., Havliecek, M., Brechtel, F.J., Russel, L.M., Weber, R.J., Gras, J., Hudson, J.G., Litchy, M (1997). Intercomparison Study of the Size-Dependent Counting Efficiency of 26 Condensation Particle Counters, *Aerosol Sci. and Techn.*, 27, 224-242.