Multi-angle scattering measurement chamber for structure factor measurement

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Soot particles have a fractal-like shape, are produced during incomplete combustion processes and are a major constituent in the atmosphere. These fractal-like particles have a self-similar structure and are composed of spherical primary particles (monomers) of black carbon. Due to the fractal-like shape, the number of primary particles scales as a power law with the characteristic size of the aggregate, where the exponent is called the fractal dimension (Df). Combustion generated aerosol particles are usually not pure soot particles but rather a complex mixture of black carbon, organic matter, sulphate, ash and other components. Therefore, dependent on the combustion process, these particles can also have different shapes varying between highly fractal-like and almost spherical. Measuring the angular light scattering of combustion originating aerosol particles in the power law regime can give us information on the shape of these particles.

At the University of Applied Sciences Northwestern Switzerland an instrument was developed in order to measure the angular light scattering of combustion generated aerosols. It measures the scattering signal simultaneously at seven different angles and at two different wavelengths (405 and 852 nm) with a time resolution of some seconds. This setup makes it possible to probe the structure factor of aerosols with high time resolution and therefore e.g. to observe fast structural changes of the aerosol particles that are expected to happen in fires during the different burning phases.

Figure 1 shows the angular light scattering of Cast (combustion aerosol standard) soot particles of different size, which were size selected by a differential mobility analyser (DMA). The data is represented in the q-space, which represents the magnitude of the scattering wave vector. The measured data was fit by the Rayleigh-Debye-Gans theory for fractal aggregates (Dobbins and Megaridis, 1991) that are shown as solid, coloured lines in Figure 1. In the power-law regime (at high q values, where the scattering appears as a line on the log-log scale), the negative slope corresponds to the fractal dimension of the particles.

For Cast soot, it seems that the fractal dimension of the generated particles does not depend on their size except for the smallest investigated mobility diameter of 100 nm where the fractal dimension is slightly higher (2.14) compared to the other particle sizes (~1.97). As it is expected, the fitted radius of gyration increases with the selected particle size, a higher "jump" is visible between the nominal DMA size of 100 nm and 150 nm from 125 to 173 nm, after that only a slight increase is visible.

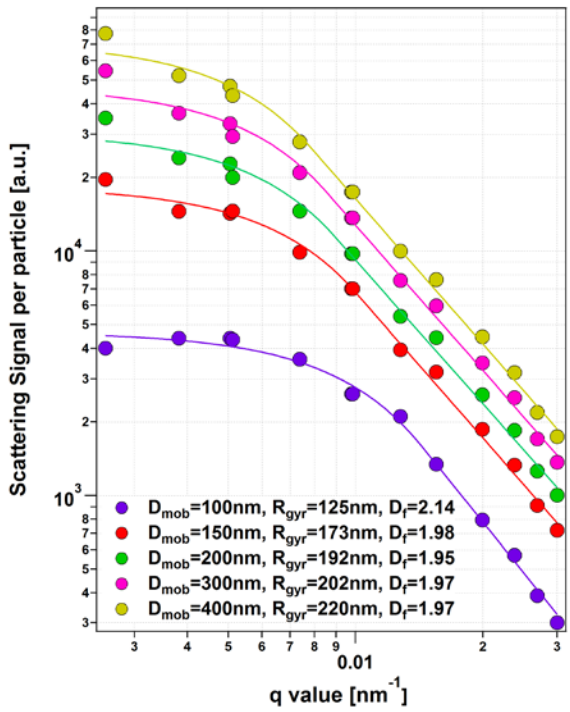

Figure 1. Normalised scattering signal for Cast soot particles as function of the magnitude of the scattering wave vector. The differently coloured lines represent the different selected nominal diameter of the DMA.

Several other experiments were also conducted on aerosols with different shapes such as highly fractal-like Palas soot, spherical paraffin oil particles and different kinds of combustion originating particles (e.g. wood burning). We have seen that the fractal-like and spherical particles can be well separated based on their angular light scattering patterns. Smouldering fires on average produced more spherical particles than flaming ones, where lower fractal dimensions were observed. This finding can be used to identify the different burning phases during combustion processes.

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Dobbins, R.A., Megaridis, C.M. (1991) Absorption and scattering of light by polydisperse aggregates. Applied Optics 30, 4747-4754.