Soot selective size distribution measurement. A demonstrative study

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In this work we propose a novel methodology for soot selective size distribution measurement using instrument combination of multi wavelength photoacoustic spectrometer (4λ-PAS) and differential mobility particle sizer (SMPS). We experimentally demonstrated that the phase of the photoacoustic signal depends on the characteristic size of the soot aerosol. The experimental result is agreed well with the theoretical calculation using the excitation parameter of the laser and microphysical properties of the aerosol. The inherent phase shift of the instrument was considered in fitting procedure. The particle related phase shift not, but the inherent instrument phase shift shows definite wavelength dependency. The inherent instrument phase shift shows decreased tendency towards the longer wavelength.

Background – the size distribution and the number-concentration of the carbonaceous particulate matter (CPM) dispersed in the atmosphere is critical issue in many perspectives i.e., climate and health effect of CPM. Despites of its importance there are no existing methodology for soot selective size distribution and number-concentration measurements of atmospheric soot aerosol. The photoacoustic spectroscopy is the only method which can measure the soot aerosol spectral responses selectively. Moreover, Moosmüller et al [1] has theoretically verified that the phase of the photoacoustic signal depends on the characteristic size of the soot aerosol. Therefore, take advantage of the synergy of selectivity and size dependency of the PA signal makes possible to investigate the size of the soot aerosol in a selective way. In this work we propose a demonstrative study for soot selective investigation of the size of soot aerosol assembly.

Methods – The investigation of the size dependency of the phase of the photoacoustic signal was made in the set up described in Fig.1. The soot assembly was generated by laser ablation. For the selection of the given size and the counting of the size selected aerosol assembly differential mobility analyzer (DMA - GRIMM, model 5403 with Kr85 neutraliser model) was used in a closed loop configuration. For the measurement of the photoacoustic signal phase at four different wavelength multi-wavelength photoacoustic spectrometer (4λ-PAS) was used. The operational principle and the characteristic parameters of 4λ-PAS is described in an earlier study [2].

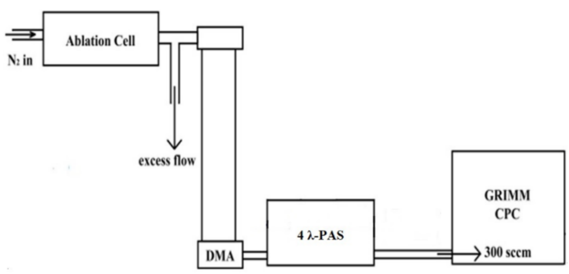

Fig. 1. Experimental set up for the measurement of PA phase in the function of particle size

Results – The PA phase measured at four different sizes (200 nm, 400 nm, 600 nm, 800nm) at the operational wavelength of 4λ-PAS and the theoretically calculated phase in the 10nm to 850nm size domain are showed in Fig.2. since the theoretical calculation does not take into account the inherent phase shift of the instrument simple translation of the calculated function was made to fit the theoretically calculate values to the measured data. the translation value was arbitrary determined by the differences of the measured at calculated values at 200nm size at all wavelengths. One can see form the figure that the measured and the calculated values agreed well in the whole size domain. However, the inherent instrument phase shift shows wavelength dependency resulted in decreasing values in phase towards the longer wavelength. However, it is worth to note that the inherent phase shift of the instrument is not correlated anyhow to the phase shift associated to the particle cooling period in the photoacoustic signal generation.

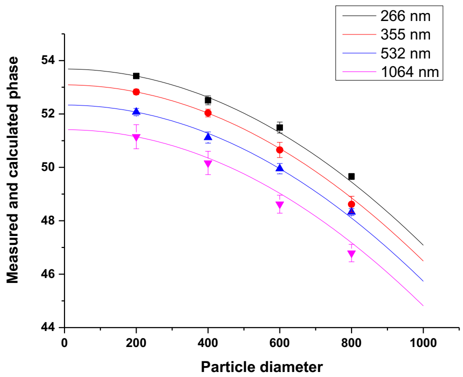

Fig.2. Measured and calculated phase of the generated soot assembly at a given size and the whole size domain using the operational wavelength of the 4λ-PAS.

Conclusions – In this study we experimentally confirmed first that the phase of the photoacoustic signal is depends on the size of the particles. We also verified that considering the inherent instrument phase shift (which is depends on the wavelength) the theoretically calculated and the experimentally measured phase are goes together in the investigated size domain. Finally, we experimentally demonstrated that the instrument combination of 4λ-PAS and SMPS makes possible to chemically selective size distribution measurement of atmospheric soot.

References

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