Photoacoustic Investigations on Single Optically Levitated Aerosol Droplets

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Here we present a photoacoustic (PA) system suitable for the direct measurement of the optical absorption of a single, optically trapped nanodroplet. The system described here is able to reveal PA absorption signals from single attoliter droplets with diamters below 1 µm diameter. Beyond principle feasibility of this new single particle characterization method, we were able to demonstrated nanofocusing in such particles based on the time-resolved monitoring of photokinetics (Cremer *et al* 2016).

The trap, which was described earlier *by David et al* in 2015, employs two counter propagating laser beams (λ = 660 nm, ~ 200 mW), The trap is suitable to hold particles below 100 nm diameter in a tight and stable confinement. The photoacoustic sensing device consists of a longitudinal acoustic resonator with a length of 40 mm and a diameter of 2 mm (Haisch and Niessner, 2012). Optical access is possible from along two axis, one along the acoustic resonator tube, which serves for the PA excitation laser, another one, orthogonal to this axis, is used for the optical trap. The PA signal is excited by a λ = 445 nm excitation laser (Nichia laser diode NDB7112E) of variable power (0.3 – 40 mW) modulated at the resonance frequency of the PA-resonator of 3.97 kHz. The PA signal is collected by an electret microphone, which is positioned orthogonal to both, the excitation beam and the trapping beam. A commercial lockin amplifier detects the modulated signal with integration times of 30 ms and 200 ms. The droplet size inside the trap can be determined based on optical interference.

Alternative to this PA cell, a small chamber equipped with a quartz tuning fork for PA signal detection was tested. The so-called Quartz-enhanced PA measurement is published to be highly sensitive for gas-phase measurements (Kosterev *et al* 2002). As defined by the tuning fork, this system operated by a significantly higher resonance frequency of ~32 kHz.

For test purpose we used a photoactive dye (VIS441), dissolved in tetraethylene glycol. While for gas-phase measurements the tuning fork detection is reported to be much more sensitive than microphone systems, we found only a difference in sensitivity of a factor 3 between the two techniques. The advantage of the tuning fork setup for our application is the better optical access of the system.

As it can be appreciated in Fig. 1, a strong PA signal is detected when a droplet is trapped and excited by the PA laser. In this figure, also the photobleaching of the dye becomes visible by the decay of the PA signal. This photobleaching obviously depends on the light intensity inside the droplet, which again depends on nanofocussing inside the droplet. Theoretical predictions on the size and power dependency showed a very satisfying agreement with our experimental findings.

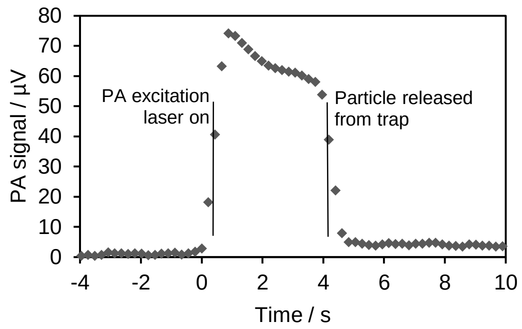

Figure 1. PA signal (microphone detection) of a single optically trapped aerosol droplet.

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