Development of a new photothermal interferometer for the in-situ measurement of carbonaceous aerosols

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Filter-based instruments are commonly used for the determination of ambient aerosol light absorption. With the assumption of a specific light absorption efficiency, the mass concentration of the light-absorbing carbonaceous particles, particularly black carbon (BC) can be determined. These methods have the advantage of being simple and robust, but the properties of the aerosol change upon deposition in the filter. These methods are prone to measurement artefacts, such as filter loading effects, increased transparency of the filter due to wetting in elevated humidity conditions, and cross-sensitivity to aerosol light scattering.

In-situ methods such as photoacoustics and photothermal interferometry (Moosmüller and Arnott, 1996; Sedlacek, 2006) measure light absorption of aerosols directly in their natural suspended state. They provide an alternative to traditional filter-based instruments. Measurements performed with these techniques are independent of aerosol light scattering and loading effects. Resonant photoacoustic measurements, however, are susceptible to changes in the resonant frequency caused by environmental influences, and suffer from measurement artefacts when absorbing gases are present. In a photothermal interferometer, the aerosols are drawn through a set of measurement chambers where a pump laser illuminates the sample. A small part of the laser light is absorbed by the sample and heat is transferred to the air, locally increasing the temperature, reducing the density and the refractive index. This perturbation is measured with a sensitive interferometer: the change of the refractive index in one arm of the interferometer relative to the unperturbed arm is measured as a change in phase. The pump laser is modulated and the signal at this modulation frequency increases the measured signal.

We present our latest development of a new photothermal interferometry setup (Visser et al., 2020). The use of only one single laser beam allows for a compact optical set-up and significantly easier alignment compared to standard dual-beam photothermal interferometers, making it ideal for field measurements. Due to a unique configuration of the reference interferometer arm, light absorption by aerosols can be determined directly – even in the presence of light-absorbing gases. The instrument can be calibrated directly with light-absorbing gases, such as NO_2, and can be used to calibrate other light absorption instruments. Our current detection limit (1 σ, 120s averaging time) is ~40 ng/m^3 BC.

In new projects, we are investigating the possibility of further significant miniaturization of our existing setup. A unique kind of photothermal interferometer is currently realized using optical fibers and waveguides. Such a miniaturized sensor has many key advantages: It will be smaller, lighter and cheaper than existing BC instruments, which are expensive and rather immobile. The miniaturization into a fully integrated optical circuit board will make it also less susceptible to external vibrations and misalignment. Our goal is to develop a novel miniaturized PTI instrument that can be used airborne to detect the local distribution of BC particles with high temporal resolution.

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